MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 92 No. 4

1932 FEBRUARY 12

ANNUAL GENERAL MEETING

Dr. H. Knox-Shaw, President, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The Report of the Auditors of the Treasurer's accounts for the year 1931 was read, and is given on p. 239.

The Annual Report of the Council was partly read.

The President delivered an Address on the award of the Gold Medal to Dr. R. G. Aitken, to whom the Medal had been awarded for his work on Double Stars (see p. 354).

The President announced that Dr. Aitken would deliver the George Darwin Lecture at the Ordinary Meeting of the Society on May 13.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 361.

During an interval, Dr. Comrie demonstrated a Willis Navigating Machine; Dr. Jackson spoke on double star observers who have been Gold Medallists of the Society; and Dr. Spencer Jones spoke on the Ross map of the Milky Way.

The thanks of the Meeting were given to the retiring members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

The election by the Council of the following Fellows was duly confirmed :—

Clyde Fisher, Ph.D., LL.D., Curator of Astronomy, American Museum of Natural History, 77th Street and Central Park West, New York City, U.S.A. ; and

Harry A. Whittaker, B.A., 48 Vegal Crescent, Ovenden, Halifax.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Douglas Richard Proctor Coates, 229 Niagara Street, Winnipeg, Manitoba, Canada (proposed by Mary Proctor) ;

Henry Rainsford Hulme, B.A., Gonville and Caius College, Cambridge (proposed by W. M. Smart) ;

Govind Padmanabha Rao, M.A., Observatory, Survey of India, Dehra Dun, U.P., India (proposed by A. A. Narayana Aiyar) ;

Stanley Skewes, M.A., Lecturer in Mathematics, University of Cape Town, S. Africa (proposed by Alan Fletcher) ;

Rev. W. M. Tate-Stoate, Belle Vue, Blockley, Worcs. (proposed by S. Chapman) ; and

Alan Herries Wilson, M.A., Emmanuel College, Cambridge (proposed by W. M. Smart).

REPORT OF THE COUNCIL TO THE HUNDRED AND TWELFTH ANNUAL GENERAL MEETING OF THE SOCIETY.

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Honorary Member	Fellows		Associates	Total
				Compounders	Annual Subscribers		
1930 December 31	1	3	1	221	699	48	973
Since elected	...	...	...	+ 4	+56	...	...
Deceased	...	...	...	−12	− 9	−3	...
Resigned	...	...	...	...	−23	...	...
Since compounded	...	...	...	+ 3	− 3	...	...
Removed from list	...	...	...	...	−12	...	...
Restored to list	...	...	...	...	+ 2	...	...
1931 December 31	1	3	1	216	710	45	976

Cash

RECEIVED

	£	s.	d.	£	s.	d.
Balances, 1931 January 1 :—						
In hand of Assistant Secretary on Petty Cash Account ...	7	6	11			
At Bankers', on Current Account	360	2	4			
At Bankers', on Deposit Account	475	10	7			
At Bankers', on " C " Account (Trust Funds)	120	3	7			
				963	3	5
Received on account of Dividends :—						
£1250 Metropolitan Consolidated 3% Stock	37	10	0			
£2000 Swansea Corporation 3½% Stock	70	0	0			
£2287, 6*s.* 9*d.* East Indian Railway 3% Stock	51	17	8			
£5125 London, Midland and Scottish Railway 4% Stock...	158	17	6			
£750 London, Midland and Scottish Railway 4% Consolidated Preference Stock	23	5	0			
£2400 Gas Light & Coke Co. 3% Debenture Stock ...	55	16	0			
£2000 Commercial Gas Co. 3% Debenture Stock	45	0	0			
£4877, 12*s.* 6*d.* War Loan Inscribed 5% Stock	243	17	6			
£419, 17*s.* 11*d.* Conversion Loan 4½% Stock, 1940/44 ...	18	17	10			
£695, 16*s.* 0*d.* Conversion Loan 3½% Stock, 1961... ...	24	7	0			
Interest on Deposit Account	17	10	8			
Income Tax refunded, 1930 April–1931 April	98	0	8			
	844	19	10			
Sales of Publications £363 15 8						
Reprints 65 0 7						
	428	16	3			
Sales of Photographs	54	5	0			
Miscellaneous Receipts :—						
London Mathematical Society, expenses of Meetings, etc. £30 0 0						
Asst. Secretary and Clerk, Pension Premiums 19 5 0						
Sale of Periodicals, Old Stereo Plates, etc. ... 113 7 0						
Donations to General Fund 7 16 0						
Postages repaid... ... ... 3 13 4						
Use of Telephone 0 8 7						
Excess on Subscriptions 1 6 0						
	175	15	11			
				1503	17	0
Received on account of Subscriptions :—						
580½ Annual Contributions (including 3 Institutional Membership fees) +1*s.*	1219	2	0			
30 Annual Contributions 1932 in advance (including 1 Institutional Membership fee)	63	0	0			
3 Annual Contributions 1933–35 in advance	6	6	0			
60 Admission Fees (including 3 due in 1930)	126	0	0			
56 First Contributions (including 3 due in 1930)	111	6	0			
Arrears paid off :—						
11 for 1929 ... ... £23 2 0						
44 for 1930 ... ... 92 8 0						
	115	10	0			
				1641	4	0
Compositions				180	12	0
Trust Funds Dividends :—						
£1212, 13*s.* 3*d.* East Indian Railway 3% Stock	27	10	4			
£542, 18*s.* 2*d.* India 3½% Stock	19	0	0			
£1934, 10*s.* 2*d.* 5% War Stock, 1929/47	96	14	6			
Income Tax refunded, 1930 April–1931 April	8	3	6			
Donation from General Fund (balance of George Darwin Lecture fee)	1	3	8			
				152	12	0
				£4441	8	5

Examined and found correct.
(Signed) A. J. THOMPSON.
H. W. NEWTON.

1932 *January* 20.

Account

PAID

	£ s. d.	£ s. d.
Assistant Secretary : Salary	250 0 0	
Clerk : Salary	175 0 0	
Assistant Secretary and Clerk for work done for London Mathematical Society in 1930	10 0 0	
Extra Library Assistance	2 0 0	
Pension Premiums for Assistant Secretary and Clerk	57 15 0	
Porter and Wife : Wages	154 16 6	
Health and Unemployment Insurance	6 13 3	
		656 4 9
Licence for Porter	0 15 0	
Fire and Accident Insurance	15 15 3	
Telephone	13 10 1	
Telegraphic Address and Time Signal	7 2 8	
Water Rate	13 2 6	
		50 5 6
Postage and Packing (including postage of *Monthly Notices*, etc., £107, 18*s.* 11*d.*)		158 14 1
Printing, etc. :—		
Monthly Notices (Vol. **91**, Nos. 1–9)	1270 3 6	
Geophysical Supplements (Vol. **2**, Nos. 7, 8)	164 3 6	
Reprints	144 5 0	
List of Fellows	58 5 2	
Miscellaneous	69 4 0	
Photo-engraving :—		
Monthly Notices £65 16 4		
Geophysical Supplements 2 5 0		
	68 1 4	
		1774 2 6
Reproduction of Photographs for sale		104 0 4
Stationery and Office Expenses	30 4 10	
Duplicating Machine for Office	20 8 0	
Library Equipment and Binding	47 16 2	
Purchase of Books (General Fund)	4 16 0	
Subscription to International Telegrams Bureau	5 0 4	
Subscription to Committee on Library Co-operation	1 1 0	
Coal, Gas, Electric Light, Firewood	108 3 3	
House Expenses and Laundry	22 1 1	
Fittings and Repairs (including completion of Decorating Account, 1930)	70 5 11	
Five Gold Medals (one engraved)	65 6 6	
Legal Charges	1 1 0	
Balance of George Darwin Lecture Fee	1 3 8	
Miscellaneous Expenditure	12 18 6	
Expenses of R.A.S. Meetings and Committees	18 7 8	
Expenses of Geophysical Meetings	5 18 9	
Expenses of L.M.S. Meetings	6 1 8	
Bank Charges and Cheque-Book	1 11 10	
		422 6 2
		3165 13 4
Expenditure on Trust Accounts :—		
George Darwin Lecture	50 0 0	
Turnor and Horrocks Fund (Library)	19 4 4	
Harry Watson Fund (Library)	57 8 4	
Lee and Janson Fund	10 0 0	
Jackson-Gwilt Fund	25 0 0	
		161 12 8
Balances, 1931 December 31 :—		
In hand of Assistant Secretary on Petty Cash Account	12 5 8	
At Bankers', on Current Account	313 1 3	
At Bankers', on Deposit Account	675 10 7	
At Bankers', on " C " Account	111 2 11	
Cheque not yet credited	2 2 0	
		1114 2 5
		£4441 8 5

Revenue

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account	3165	13	4			
,, Reserve for Accounts due but not presented...	200	0	0			
	3365	13	4			
Less Reserve for Accounts due 1930 now written back ...	305	0	0			
				3060	13	4
,, Amount transferred to Composition Fees Reserve Fund in 1931...				180	12	0
,, 24 Annual Contributions in Arrear written off	50	8	0			
,, 14 Annual Contributions 1931 written off as per contra ...	29	8	0			
				79	16	0
,, Due for Publications and Postage, 1929 and 1930, written off				0	16	1
Excess of Income over Expenditure, 1931				51	3	8
				£3373	1	1

Examined and found correct.

(Signed) A. J. THOMPSON.
H. W. NEWTON.

1932 *January* 20.

Account, 1931

		£	s.	d.	£	s.	d.
By Subscriptions—							
	580½ Annual Contributions 1931 (plus 1*s.*), including 3 Institutional Membership Fees	1219	2	0			
	22½ ditto (less 1*s.*) paid in 1928 and 1930, now matured ...	47	4	0			
	72 ditto, outstanding	151	4	0			
	14 Contributions for 1931 due, but unpaid, in respect of Fellows died, resigned, or names removed, and written off per contra	29	8	0			
					1446	18	0
,,	50 First Contributions, 1931, at 2 guineas...	105	0	0			
	3 ditto, at 1 guinea	3	3	0			
	3 ditto, outstanding	3	3	0			
	56				111	6	0
,,	57 Admission Fees, 1931	119	14	0			
	3 ditto, outstanding	6	6	0			
	60				126	0	0
,,	5 Composition Fees at 30 guineas...	157	10	0			
	2 ditto, reduced	23	2	0			
	7				180	12	0
,,	6% of Composition Fees Reserve Fund as per Balance Sheet, transferred to Current Revenue				26	6	9
,,	Sundry Debtors, 1931				24	5	9
,,	Dividends, Sales of Publications and Photographs, and Miscellaneous Receipts, as per Cash Account	1503	17	0			
Less	Payments due 1929 and 1930 (£55, 9*s.* 7*d.*, *less* 16*s.* 1*d.* written off and £1, 19*s.* 0*d.* still outstanding) £52 14 6						
	Advance payments for *Monthly Notices*, Vol. **92** 74 11 6						
	Overpayments on publications, 1931 ... 0 17 11						
	Income Tax 1930 April–December, refunded in 1931 ... ... 59 12 8						
		187	16	7			
					1316	0	5
,,	Payments for *Monthly Notices*, Vol. **91**, received in 1930 and now matured				79	4	0
,,	Income Tax (General Fund) deducted at source 1931 April 6–December 31, not yet refunded				62	8	2
					£3373	1	1

Balance Sheet

LIABILITIES

	£ s. d.	£ s. d.
30 Subscriptions for 1932, paid in 1931	63 0 0	
3 Subscriptions, 1933–35, paid in 1931	6 6 0	
		69 6 0
Sundry Creditors for Accounts due but not presented ...		200 0 0
Cash Balances (Income) of Trust Funds—		
Turnor and Horrocks Fund	4 0 2	
Harry Watson Fund	46 12 3	
Lee and Janson Fund	16 9 6	
Hannah Jackson Fund	19 6 11	
George Darwin Lectureship Fund	24 14 1	
		111 2 11
Trust Funds (Capital), as per contra		2,949 17 0
Income Tax on Trust Funds, 1931 April 6–December 31, not yet refunded, as per contra		6 16 5
Special Fund (Capital), as per contra		1,457 6 5
Composition Fees Reserve Fund—		
As at 1930 December 31	258 7 2	
Received in 1931	180 12 0	
	438 19 2	
Less 6% transferred to current revenue	26 6 9	
		412 12 5
Advance payments for *Monthly Notices*, Vol. **92**	74 11 6	
Credits for overpayments on publications, 1931	17 11	
		75 9 5
General Fund—		
As at 1930 December 31	15,982 12 11	
Add Excess of Income over Expenditure, 1931	51 3 8	
		16,033 16 7
		£21,316 7 2

Examined and found correct.

(Signed) A. J. THOMPSON.
H. W. NEWTON.

1932 *January* 27.

1931 *December* 31

ASSETS

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrears—		
21 for 1930	44 2 0	
72 for 1931	151 4 0	
3 First Contributions, 1931, outstanding	3 3 0	
3 Admission Fees, 1931, outstanding	6 6 0	
		204 15 0
Sundry Debtors, 1930		1 19 0
Sundry Debtors, 1931—		
Due for Publications and Reprints	21 12 10	
Due for Photographs	2 6 0	
Due for Postages	0 6 11	
		24 5 9
Investments, General Fund, valued as on 1922 December 29, or date of purchase if later *		15,494 17 0
Investments of Special Fund, valued as at dates of purchase *		1,457 6 5
Investments of Trust Funds, valued as on 1922 December 29, or dates of purchase if later *		2,949 17 0
Income Tax 1931 April 6–December 31, not yet refunded—		
General Fund	62 8 2	
Trust Funds	6 16 5	
		69 4 7
Sundry Balances—		
In hand of Assistant Secretary on Petty Cash Account ...	12 5 8	
At Bankers', on Current Account	313 1 3	
At Bankers', on Deposit	675 10 7	
At Bankers', on " C " Account (Trust Funds)	111 2 11	
Cheque not yet credited	2 2 0	
		1,114 2 5
		£21,316 7 2

Astronomical and other Manuscripts, Books, Prints, Photographs and Instruments.
Furniture, etc.
Stock of Publications and Photographs for sale.
Four Gold Medals.
Four Bronze (Jackson-Gwilt) Medals.
} Not valued.

* Owing to the general financial uncertainty the investments have been taken at the same value as in last year's balance sheet, in accordance with a resolution of Council.

J. H. R.

INVESTMENTS

As at 1931 December 31

General Fund

£1250 Metropolitan 3-per-cent. Stock.
£2000 Swansea Corporation 3½-per-cent. Stock.
£2287, 6*s*. 9*d*. East Indian Railway 3-per-cent. Debenture Stock.*
£5125 London, Midland and Scottish Railway 4-per-cent. Debenture Stock.*
£750 London, Midland and Scottish Railway 4-per-cent. Consolidated Preference Stock.*
£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.*
£2000 Commercial Gas Co. 3-per-cent. Debenture Stock.*
£4352, 12*s*. 6*d*. 5-per-cent. War Loan Inscribed Stock, 1929–47.

Grove-Hills Special Fund

£525 5-per-cent. War Loan Inscribed Stock, 1929–47.
£419, 17*s*. 11*d*. Conversion Loan 4½-per-cent., 1940–44.*
£695, 16*s*. Conversion Loan 3½-per-cent., 1961.

Five Trust Funds

£1212, 13*s*. 3*d*. East Indian Railway 3-per-cent. Stock.*
£542, 18*s*. 2*d*. India 3½-per-cent. Stock.
£1934, 10*s*. 2*d*. 5-per-cent. War Loan Inscribed Stock, 1929–47.

* Taxed at source.

REPORT OF THE AUDITORS FOR THE YEAR 1931

We have examined the Treasurer's accounts for the calendar year 1931, and have certified them to be correct. The investment holdings have been certified by the Bank of England and by the Westminster Bank respectively.

Attention may be invited to a few items in these accounts. The expenditure on printing *Monthly Notices*, **91**, was £1270, 3*s*. 6*d*., and was greater by £329 than the average expenditure during the previous ten years. We understand that the increase in the size of page will involve an increase in cost in future of about £50 per annum. The expenditure on printing the *Geophysical Supplements*, which fluctuates rather widely, was £164, 3*s*. 6*d*. in 1931, or £50 greater than the average of the previous nine years. The sale of the Society's publications at its own rooms results, however, in a considerable saving of about £80 a year. Other noteworthy items are the purchase of five gold medals (£65, 6*s*. 6*d*.) and of a duplicating machine (£20, 8*s*.).

The excess of income over expenditure, as shown by the Revenue Account, is £51, 3*s*. 8*d*. The sum held in reserve from compositions is £412, 12*s*. 5*d*., the net increase being £154, 5*s*. 3*d*.

The late Mr. A. F. Lindemann, a Fellow of the Society, bequeathed to the Society a sum of £1000, free of legacy duty ; this bequest has not yet been received.

A list has been laid on the table containing the names of those Fellows in arrear for sums due on 1931 January 1, with the amount due against each Fellow's name.

The books, instruments, and other effects on the premises appear to be in satisfactory order. None of the seven missing volumes named in the Auditors' Report for 1930 has been recovered. So far as is known, no other volumes are missing. Two sets of volumes have been sold during the year, namely, the *Proceedings of the London Mathematical Society* and *Acta Mathematica*. For these, the sum of £71, 5*s*. has been received. We understand that the sale is due primarily to pressure on shelf-space. Since mathematics and astronomy are so closely related, it seems regrettable that such action should have been found necessary.

We feel some apprehension regarding the risk of loss, especially by fire, to the valuable manuscripts possessed by the Society, and we recommend that inquiry be made as to whether any steps can reasonably be taken to lessen this risk.

A number of the Society's instruments have been disposed of in accordance with the scheme sanctioned by the Society at the last Annual General Meeting.

An adding machine has this year been placed at the disposal of the

Auditors. This has been of great use to us, and we wish to express our appreciation.

Finally, it is a pleasure to acknowledge our indebtedness to the Assistant Secretary, whose detailed knowledge and painstaking accuracy have lightened our labours during the audit.

(Signed) A. J. Thompson.
H. W. Newton.

1932 *February* 4

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

The John Lee Gift : In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell ; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856) : Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876) : R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877) : C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905) : Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906) : The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922) : The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock 1929–47, in memory of his father, the 3rd Earl of Rosse, who made the 6-foot reflector, and who died 1867 October 31.

The Grove-Hills Bequest (1922) : Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early astronomical and mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Lindemann Bequest (1931) : A. F. Lindemann, Esq., bequeathed to the Society the sum of £1000, free of legacy duty.

THE GROVE-HILLS SPECIAL FUND

In 1923 the then Treasurer, Col. Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. He aimed at securing £1800, and up to the present the total amount received from all sources (including dividends on the investments representing the fund) is £1913, 1*s.* 11*d.*, of which £1480, 2*s.* 10*d.* has been invested and is now represented by £525 War Stock 5 per cent. 1929–47, £419, 17*s.* 11*d.* Conversion Loan 4½ per cent. 1940–44, and £695, 16*s.* Conversion Loan 3½ per cent. 1961. Part of the cash balance has been transferred from time to time to the General Fund to meet current expenditure, and in 1930 the whole of the remaining balance (£231, 3*s.* 1*d.*) was thus transferred, as a contribution towards the expenses of decorating the Society's premises. In 1928 the Council resolved that the interest on the investments of the Special Fund should be regarded as part of the general income of the Society, and no longer funded.

TRUST FUNDS

The Lee and Janson Fund : In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1931 Jan. 1. Balance of Fund	16	12	5	1931. Grant from Fund ...	10	0	0
1931. Dividends, East Indian Railway ...	7	11	11	1931 Dec. 31. Balance of Fund	16	9	6
Income Tax, 1930 April–1931 April, refunded ...	2	5	2				
	£26	9	6		£26	9	6

The Turnor Fund and the Horrocks Memorial Fund : In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks : to this the Society added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East Indian Railway

3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the library.

	£	s.	d.		£	s.	d.
1931 Jan. 1. Balance of Fund	6	10	1	1931. Purchase of Books ...	19	4	4
1931. Dividends, East Indian Railway ...	12	17	11	1931 Dec. 31. Balance of Fund	4	0	2
Income Tax, 1930 April–1931 April, refunded ...	3	16	6				
	£23	4	6		£23	4	6

The Harry Watson Memorial Fund : In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* 0*d.* to the Society, which now stands invested in £946, 6*s.* 11*d.* 5-per-cent. War Stock 1929–47. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

	£	s.	d.		£	s.	d.
1931 Jan. 1. Balance of Fund	37	14	3	1931. Purchase of Books ...	23	2	10
1931. Dividends, India 3½ per cent.	19	0	0	Binding	34	5	6
Dividends, War Stock 5 per cent.	47	6	4	1931 Dec. 31. Balance of Fund	46	12	3
	£104	0	7		£104	0	7

The Hannah Jackson (née Gwilt) Fund : In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock ; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	s.	d.		£	s.	d.
1931 Jan. 1. Balance of Fund	35	4	7	1931. Gift from Fund ...	25	0	0
1931. Dividends, East Indian Railway ...	7	0	6	1931 Dec. 31. Balance of Fund	19	6	11
Income Tax, 1930 April–1931 April, refunded ...	2	1	10				
	£44	6	11		£44	6	11

The George Darwin Lectureship Fund : In 1926 June, the then President, Dr. J. H. Jeans, presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George Darwin Lectureship*, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum has been invested in £988, 3*s*. 3*d*. 5-per-cent. War Stock 1929–47, and the income will be annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

	£	*s*.	*d*.		£	*s*.	*d*.
1931 Jan. 1. Balance of Fund	24	2	3	1931 May. Lecture Fee ...	50	0	0
1931. Dividends, War Stock 5 per cent.	49	8	2	1931 Dec. 31. Balance of Fund	24	14	1
Donation from General Fund	1	3	8				
	£74	14	1		£74	14	1

CELESTIAL PHOTOGRAPHS

The following have been added to the list of celestial photographs reproduced by the Society for sale to the Fellows :—

R.A.S.
Ref. No.

421. Solar Spectrum, Infra-red to λ 9600. Diffraction Grating. Abney.
422. Spectrum of Carbon Monoxide (Fowler) and of Comet Morehouse, 1908 III (Curtis).
423. Coronal Line 5303 (without eclipse). Lyot, Pic du Midi, 1930 Aug. 10d. 10h. Exp. 6 min.
424. Passage on to Sun's Disc of Solar Prominence (K3), 1929 Aug. 26, 27, 28, 29. Meudon Observatory.
425. Chromospheric Spectra, H, K. α Boötis, H2, H3, and K2, K3 ; Sun, H1 and K1 ; α Aurigæ, H2 and K2. Meudon Observatory.
427. Milky Way, Centaurus—Scorpio. Exp. 2h. Rect. lens. Ap. 0·5 in. F.L. 6 in. Steavenson.
428. Milky Way, Scorpio—Antinous. Exp. 2h. Rect. lens. Ap. 0·5 in. F.L. 6 in. Steavenson. (Print only ; slide not yet available.)
429. Royal Astronomical Society's Rooms, Burlington House, London, W. 1.

PUBLICATIONS OF THE SOCIETY

During the past year the Society has published *Monthly Notices*, vol. **91** ; and *Geophysical Supplements*, vol. **2**, Nos. 7, 8.

OBITUARY

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—James Baikie
Alfred Allinson Bourne
James Stark Browne
Ernest Reginald Bryan
Edward Carpmael
John Brise Colgrove
George Craig
Charles Douglas Percy Davies
William Frederick Denning
Frank Campbell Dumat
Daniel Dutton
Crawford Muir Fleming
James Arthur Formoy
Sir Howard Grubb
G. P. Blackwood Hallowes
Thomas Laing
Adolph Friedrich Lindemann
Charles James Merfield
Gustavus William Nicolls
Sir Charles Parsons
*Benjamin Thomson

Associates:—Solon I. Bailey
Albert Abraham Michelson
Alfred Wolfer

JAMES BAIKIE was born at Lasswade, near Edinburgh, on 1866 November 25. Educated at George Watson's College and Edinburgh University, he proceeded to the study of theology at New College, Edinburgh, with a view to the ministry of the Free Church of Scotland. On the completion of his theological course, he was ordained minister of Ancrum, Roxburghshire, in 1892. Here he ministered until his translation to the suburban charge of Wardie, Edinburgh, in 1912. After eleven years in this sphere he was called to Torphichen in West Lothian in 1923. Ill-health compelled his resignation from this charge in 1927.

In his student days Baikie developed a keen interest in astronomy, and during his ministry at Ancrum he devoted a great deal of time to its study. He observed systematically and made many drawings of the planets, chiefly Jupiter. While at Ancrum, too, he published his first book, *Through the*

* Died 1924. Death not notified till 1931.

Telescope, a useful and informative summary of the astronomy of the time, with chapters on the art of observing specially helpful to amateur astronomers. A volume entitled *Peeps at the Heavens* appeared some years later.

Baikie's interest in astronomy led him to the study of Egypt and the ancient East, and latterly this absorbed most of his leisure time. He wrote extensively on the subject, and many volumes stand to his credit. He was appointed Oxford University Extension Lecturer on Egyptology in 1924, and four years later the University of Edinburgh, in recognition of his work in Egyptology, conferred on him the degree of Doctor of Divinity.

Dr. Baikie died at his home at Broomieknowe, Lasswade, on 1931 February 5. He is survived by his widow and two sons.

He was elected a Fellow of the Society on 1892 June 10.

H. M.

ALFRED ALLINSON BOURNE was born in 1848 at Atherstone, in Warwickshire, the third son of Mr. William Bourne, of Oakfield, Atherstone. He went in 1863 as a scholar to Rugby, where he was successful both in work and at games. In the latter he came to the fore primarily as a slow left-hand bowler. From Rugby he went up to Cambridge as a scholar of St. John's College; in 1871 he was seventeenth wrangler and he also obtained a second class in the Classical Tripos. He played in the famous cricket match of 1870, when Cambridge won by two runs after Oxford required only four runs to tie, with three wickets in hand. Cobden took the three wickets in one over, two clean bowled and the third man (Butler) caught by Bourne at mid-off. In *Fifty Years of Sport* Cobden's own account of his historic over is given ; in it he says : " Two bits of fielding by Bourne at critical moments turned the evenly poised scale. In the penultimate over he saved an apparently certain four when fielding at short leg ; and it was no ordinary catch which dismissed Butler, who hit at the ball for all he was worth and fairly got hold of it." It may be added that in Oxford's first innings Bourne bowled Ottaway for 16.

As soon as he had taken his degree Bourne went to Rossall as head mathematical master, and there he began writing his mathematical books. He was appointed head of the Oxford Military College in 1881. Later he coached for some years in Cambridge. His last appointment was as head mathematical master at Cheltenham College, where he remained for 18 years. Mr. Bourne collaborated with Mr. W. Baker in mathematical books which are used in schools in many parts of the world. He married, in 1890, Harriett Collins, who died in 1924. In the later years of his life he took a great interest in geophysics. He died at Cheltenham on 1931 July 17. He leaves two daughters, Mrs. Bower and Mrs. Anson.

He was elected a Fellow of the Society on 1927 November 11.

JAMES STARK BROWNE was born at Bath in 1853. He was for the greater part of his life engaged in business. He was fond of travel and all his life was an enthusiastic student of astronomy. He wrote astronomical articles for magazines, and lectured in Ealing and elsewhere. As a resident

in Ealing for many years, he was a regular attender of the meetings of the Society, and also of the British Astronomical Association. In 1900 he went to Algiers to view the total solar eclipse.

He had many hobbies—gardening, photography, microscopy, philately. He was a good elocutionist and Shakespearian actor, and wrote several books of poetry in which his deep piety and a reverence for the mysteries of life and nature found expression. One who knew him well wrote: " His genial affectionate heart won our love, his staunch sincerity our esteem, his poetic and artistic gifts our admiration." He married in 1887, and is survived by his widow, three daughters, and two sons. He died at Bexhill-on-Sea on 1931 May 14 from heart trouble, which had curtailed his activities for several years.

He was elected a Fellow of the Society on 1891 January 9.

ERNEST REGINALD BRYAN was born at Kettering on 1888 July 24. By profession he was a chartered accountant and was employed in the firm of Bird & Co. of 7 Gracechurch Street, London. At the beginning of the Great War, Bryan joined the Public Schools Battalion and served uninterruptedly from 1914 August to 1919. As a Captain in the 7th Gloucestershire Regiment he fought for three and a half years in Mesopotamia. It was during this period of active service that he contracted malaria and dysentery, thus sowing the seeds of ill-health which led to his untimely death at the early age of forty-three. He died in a nursing home near Guildford on 1931 December 29. He was unmarried.

He was elected a Fellow of the Society on 1925 April 8.

JOHN BRISE COLGROVE was born at Swanbourne, Bucks, in the year 1840. He was a schoolmaster by profession, and he held a temporary headship of a Preparatory Boys' School at the early age of seventeen. Later he entered Pembroke College, Cambridge, of which he was a scholar. At Rossall he was second master, in charge of the Modern side of the school. He was subsequently headmaster of Loughborough Grammar School, from which he retired several years ago. He was an enthusiastic mountaineer and an old member of the Alpine Club. He is mentioned in Whymper's book as the first man, in company with his two friends, Cawood and Cust, to climb the Matterhorn without guides.

Mr. Colgrove never married. He died at Loughborough on 1931 October 29 at the age of ninety-one years.

He was elected a Fellow of the Society on 1875 November 12.

CHARLES DOUGLAS PERCY DAVIES was born at Tewkesbury, Gloucestershire, on 1856 September 12, and was the son of Canon Charles Greenall Davies, at that time vicar of the parish. Educated at Cheltenham College, he passed with a classical scholarship to Pembroke College, Oxford, in 1876. He obtained a second class in the Classical Moderations of 1878 and was ordained in 1880. Subsequently he held curacies at Whitchurch

(Salop), Chaceley and Red Marley (Glos.), and Ringmer (Sussex). In 1892 he was appointed Rector of East and North Marden, near Chichester. Here he worked until 1902. From then, until 1917, he held the living of Fretherne, Glos., and in 1918 moved to Deane, near Basingstoke. This was his last incumbency, and in 1927, largely owing to failing health, he retired from active clerical work and went to live at Kemerton, on the lower slopes of Bredon Hill, quite close to the scenes of his birth and early life. He died in a nursing home at Cheltenham, following an operation, on 1931 February 5, and was buried in the Cloister Garth of the old Norman Abbey at Tewkesbury. He leaves a widow, two sons and two daughters.

Davies had, apart from his family and his calling, two great interests in life—campanology and astronomy. Of these the former had perhaps the stronger hold upon him. In point of time it was certainly the first, his proficiency as a bell-ringer dating from his schooldays, when he had ample opportunities for practice in the belfries of Tewkesbury and Cheltenham. On going up to Oxford as an undergraduate he became almost at once a leading light in the University Society of Change Ringers. From that time onwards his fame as a ringer was assured, and it was not long before he came to be regarded as an authority on the art. He contributed largely to the literature of the subject, and was the author of more than one original treatise. For many years he was ringing editor of *Church Bells*, and was for nineteen years secretary of the Central Council of Church Bellringers. The esteem in which he was held may be judged from the statement, in *The Bell-Ringing Journal*, that by his death the fraternity had lost " one of the greatest figures that has ever adorned its ranks."

It was apparently some time during the 'eighties of last century that Davies first became seriously interested in astronomy. It is evident that almost from the beginning his interest was chiefly in the optical side of the subject. This is clearly shown by the nature of the papers which he occasionally communicated to this Society and to the British Astronomical Association. His first contribution to the *Monthly Notices* appeared in vol. 55 (1895), and dealt with the suggested construction and mounting of a modified Newtonian reflector. Four years later there appeared from his pen the plan for an instrument designed for photographing the corona in full sunshine. A few years after this Davies took up the practical construction of parabolic specula, and in 1909 communicated to the Society a valuable paper embodying the results of his experience in testing these mirrors; this paper is still quite frequently quoted in the literature of the subject. His last paper in the *Monthly Notices* appears in vol. 84 (1923), and deals with his careful testing of the figure of one of Herschel's 20-foot specula.

Davies did not confine his attention to parabolic mirrors ; he was one of the few amateurs who have tackled the more difficult problem of figuring planes. At this he attained a considerable degree of success, producing mirrors up to a diameter of 12 inches. More than one of his flats has formed part of the equipment of an official eclipse expedition.

It was natural that Maunder's proposal, in 1890, to found the British

Astronomical Association should find an enthusiastic supporter in Davies. He was, in fact, one of its original members, and for some time remained a prominent figure at the meetings of the Association. Then for some years his removal to Gloucestershire caused him to appear less often at the meetings : but the end of the War found him once more within a reasonable distance of London, and his personality soon became familiar to a new generation of amateur astronomers. Finally, in 1924, to his great gratification and surprise, he was invited to accept nomination as President of the Association. This honour, accepted with characteristic diffidence, was to him the crowning-point of his astronomical career, and the genial manner in which he discharged his Presidential duties during his two years of office is still a recent and delightful memory.

He was elected a Fellow of the Society on 1889 March 8.

W. H. S.

WILLIAM FREDERICK DENNING, one of the greatest amateur astronomers of modern times, died at his home, 44 Egerton Road, Bristol, on 1931 June 9, in his eighty-third year. His father was an accountant, and Denning joined his profession, but as a lad he showed interest in astronomy and was the possessor of a $4\frac{1}{4}$-inch refractor when he was seventeen. About six years later he procured a 10-inch reflector, with which he did most of his work afterwards. In 1869 he founded a Society of Young Amateur Observers and for a time was both secretary and treasurer ; he contributed various notes to the *Astronomical Register* on different subjects, but soon he began to concentrate on that branch which gave him world-wide renown.

His first contribution to the literature of the Society was made in 1872 (*M.N.*, **33**, 93) through R. A. Proctor, as Denning was not then a Fellow. He described his observations of the Andromedid meteors and also his determination of the radiant. In 1876 April he contributed a paper to the *Monthly Notices* in which he gave a list of 27 radiant points of meteors he had observed. In 1890 May he supplied a list of 918 radiant points which he had deduced from 9177 paths observed over seventeen years.

His plan of work is of interest. Generally he looked towards the east, sitting in a chair in mild weather, but when the nights were cold he either stood or paced up and down. On the subject of meteors he contributed many papers to different journals—*The Observatory*, *Nature*, *B.A.A. Journal*, and *Monthly Notices*. The last-named for 1923 November contains a catalogue of 314 radiants found from his observations at Bristol, 1912–22, and in vol. 53 of the *R.A.S. Memoirs* there is a general catalogue of more than 4000 radiants determined by himself and others.

Dr. C. P. Olivier pays a high tribute to Denning's meteoric work in *The Observatory*, 1931 October. He says : " Probably his most outstanding discovery as to meteors was his final definite proof that the Perseid radiant moved from night to night. Once this was accepted, advances in many directions were possible. His calculations of the heights and paths of fireballs and other meteors must have run into the hundreds, and his data

will furnish indefinitely one of the richest mines for the theoretical investigator."

A considerable amount of discussion has taken place on this subject of " stationary radiants," the existence of which Denning believed he had firmly established. In consequence of the orbital motion of the Earth, it is to be expected that the radiant from any shower would show an eastward movement of about 1° in longitude from night to night, and in fact this actually occurs with many of the well-known showers. But Denning observed meteors radiating from a small area in the heavens for weeks or even months, and the theory of this presented certain difficulties. It might be assumed that there was no connection between the various streams from which these meteors emanated, but the probability of this was very small. Conditions under which stationary radiation might occur were considered by H. H. Turner, W. H. Pickering, H. C. Plummer, and M. Davidson. Some of the explanations given applied to more or less restricted conditions and failed to give satisfactory reasons for stationary radiation in all circumstances. Dr. Olivier hazards the opinion that certain methods of reduction, not observational errors, led Denning to his conclusions. He rightly remarks that " the last word has not been said upon this difficult subject."

Although Denning devoted so much time to naked-eye work, he was a great telescopic observer too. The discovery of four comets falls to his credit: 1881 V, 1890 VI, 1892 II and 1894 I. He tells us in his *Telescopic Work for Starlight Evenings* how he missed discovering a comet on 1881 July 11. He had thoughts of sweeping the Auriga region with the aid of his comet eye-piece, but, as the prospect did not seem very enticing, he gave up the idea. Only three nights later a bright telescopic comet in Auriga was discovered by Schaeberle at Ann Arbor. However, he profited by his experience on this occasion. In the same year on October 4, after he had made some observations on Jupiter before sunrise, he hesitated about comet sweeping, but remembering his previous experience, he started sweeping and almost immediately discovered a new object which afterwards proved to be a short-period comet. In the course of his sweeps for comets he discovered over 20 faint nebulæ, and was among the first group of observers to discover Nova Aquilæ on 1918 June 8. He also discovered Nova Cygni, 1920 August 20.

The most important of his planetary work was on Jupiter. He carried out systematic work on the surface features of the planet, and his observations of thousands of transits of spots over the central meridian of the disc were of great assistance in establishing the permanent nature of some of the best-defined surface currents. He was also greatly interested in the past history of special features, and in the search for possible periodicities in their appearance or motion. The red spot was an object of special interest to him, and he was able to show that the present spot and the " hollow " in the S. equatorial belt in which it is commonly seen to be lying are to be linked up with the hollow drawn by Schwabe on 1831 September 5. He connected Hooke's spot of 1664 with that observed by J. D. Cassini and recorded at intervals down to 1713 by different observers. Although more than a century passed

without any other records of its appearance, Denning was of opinion that the earlier spot and the red spot were probably the same.

The opportunities for systematic work on Saturn are not, of course, as great as in the case of Jupiter. In 1903 an eruption of spots in the N. hemisphere of the planet occurred, and from a discussion of the material available Denning derived a rotation period of about $10^h\ 38^m$, which is about 23^m longer than the period previously determined for the equatorial regions.

His work on Mars, though not very extensive, is interesting, especially that which deals with the " canal " controversy. In *M.N.*, 63, 502, 1903, he gives his opinion, which probably is shared by most observers to-day, that natural rather than artificial production is suggested by the appearance of the surface lineaments. He made observations on Venus and Mercury, but the markings which he saw were too vague to allow of any deductions on the rotation periods of the planets.

It may be some encouragement to the amateur to learn that his 10-inch With-Browning reflector, with which most of his work was done, and also the 12·6-inch Calver reflector, were mounted as altazimuths.

The following honours and awards may be a useful indication of the esteem in which Denning was held:—President of the Liverpool Astronomical Society, 1887–88 ; awarded Bronze Comet Medals by Astronomical Society of the Pacific, 1890, 1892 and 1894 ; received the Valz Prize from the Academy of Sciences, Paris, 1895 ; awarded Gold Medal of the Royal Astronomical Society, 1898 ; granted Civil Pension in 1904 ; awarded M.Sc., *honoris causa*, 1927, by the University of Bristol.

In his early days Denning was a keen cricketer. He was of a very retiring disposition, however, and although invited by Dr. W. G. Grace to play for Gloucestershire, he declined to do so. His extraordinary modesty was probably the most striking feature in his character, and his life and his work through many years of ill-health should act as a stimulus to every amateur astronomer.

He was elected a Fellow of the Society on 1877 June 8.

M. D.

FRANK CAMPBELL DUMAT was born in 1859 in Calcutta, where his parents had resided for some time. Shortly afterwards they left India, his father's engineering activities leading him to other countries. Subsequently the son proceeded to England for his studies, where he took up the profession of civil engineering, which, owing to an accident, he was compelled to abandon when his studies were nearly completed. He then adopted the legal profession and was called to the Bar (Middle Temple) and began his legal career in Johannesburg, South Africa, which was then at the beginning of its prosperous mining existence. Though Dumat participated in the excitements and variations that important mining discoveries and large business developments in a new and rich centre provided for its citizens, his extraordinarily versatile and highly trained mind could not satisfy itself with the ebullitions of prosperity around him.

A profound reader and deep thinker upon most scientific subjects, he

became much attracted to the science of astronomy, and when building himself a house had it equipped with a telescope for the continuance of his studies. Unfortunately his health was not proof against the dual stress and he had to relinquish his night work; but his interest in astronomy never waned and he always kept abreast of the developments of the subject. He continued his residence in Johannesburg and practised his profession till his death on 1931 August 13. He was on the boards of most of the leading gold companies and was prominently concerned in other important ventures which appealed to his profound scientific knowledge.

Mr. Dumat was widely respected in South Africa; his great generosity and gentle nature never refused charity and sympathy. He was one of the best loved men on the Witwatersrand.

He was married, but his wife predeceased him and he left no family.

He was elected a Fellow of the Society on 1901 January 11.

DANIEL DUTTON was born in Briely, Staffordshire, in 1848. At Robertson's Academy his studies were directed towards training him for the profession of mining engineer, and at the close of his school career he entered the office of a cousin who owned a colliery. When he had reached the age of twenty his half-brother, the Rev. Dr. William Ferguson, who was an eminent minister of the Primitive Methodist Church, appealed to him to consider the claims of the Christian ministry as his sphere of life-work. Dutton responded to this appeal and abandoned the profession for which he had all but qualified, and in which he had every prospect of attaining success. After four years of theological study he was ordained in 1872, and for five years served in more than one important circuit. It was during this period that Dutton was married and his two children were born. At the invitation of the authorities of his Church, Dutton took up in 1877 a ministerial charge at Caversham in New Zealand. After several years of devoted service there he was transferred to the Presbyterian Church of New Zealand, of which for thirty-four years he was an honoured and well-loved minister. In 1921 he was elected to the Moderatorial Chair of the Presbyterian General Assembly, in recognition of his outstanding services to the Church.

As a lecturer on scientific subjects, especially astronomy, Dutton rendered conspicuous service to communities in all corners of the island. His knowledge of astronomical subjects was accurate and comprehensive, and his genial personality and ready flow of speech secured for him a warm welcome wherever he appeared.

Dutton will be long remembered for his services as Military Chaplain. His first chaplaincy dated from 1900, when he received a commission in the Otago Volunteers. During the South African War he was nominated to accompany one of the New Zealand contingents, and although he was fifty years of age he carried out the work entrusted to him with conspicuous fidelity, tact and zeal. On the outbreak of the Great War he volunteered for active service as Chaplain, but to his intense disappointment the Chaplains' Committee were unwilling to nominate him on the score of age and the uncertainty of his health at the time. However, he was later appointed

Chaplain of the hospital ship *Maheno*, which was despatched to Gallipoli, where he had his full share of danger and excitement. At the end of 1917 he found it necessary to retire from active association with the New Zealand Expeditionary Force, and he was awarded a decoration for his long and efficient military service. He died at Dunedin on 1931 August 26, and is survived by his widow and one daughter.

He was elected a Fellow of the Society on 1877 January 12.

CRAWFORD MUIR FLEMING, who died on 1931 March 23 at the age of ninety-five, was born on 1835 April 12. He was a brother of the late Canon David Fleming, F.R.A.S., who died in 1920, aged ninety (*M.N.*, **81**, 257), and the father of Major A. D. Fleming, who has been a Fellow of the Society since 1906. Although for the last seven years Mr. Fleming had been blind, his mental faculties were alert almost to the last. He was an enthusiastic observer of the heavens, and nothing delighted him more than to chat about astronomy and to place his telescope (a 3-inch refractor) at the service of his friends. He had a deep reverence for the marvels of Nature, and his writings, and perhaps more especially his verses, were deeply appreciated by a large circle of readers at Sydenham, where he had resided for the last thirty-seven years. In 1857 he married Mary Ann Davidson, who died in 1892.

He was elected a Fellow of the Society on 1906 January 12.

JAMES ARTHUR FORMOY was born in London in 1854. For many years he was sole partner in the firm of Mellor & Formoy, of London, importers of oils. He had a very extensive knowledge of the chemistry of oils and was a Fellow of the Chemical Society. For many years the study of astronomy was his principal hobby. He was chiefly interested in the spectroscopic and photographic applications, and, although making no professional use of his knowledge, he used from time to time to give lectures upon astronomical topics, some of which were published in the *Camera Club Journal*. Within three months of his death, at the age of seventy-six, he delivered a lecture of an hour's duration to a large audience at a meeting of the Bournemouth Scientific Society. He himself prepared most of the lantern slides used for his lectures with the aid of a clock-driven telescope, a spectroscope and camera. The later years of his life were spent at St. Mawes in Cornwall, and at Bournemouth.

In 1877 Formoy married Emily Ann Reid, who died in 1915. He died on 1931 March 8 at Bournemouth, and is survived by two sons.

He was elected a Fellow of the Society on 1893 March 10.

Sir HOWARD GRUBB.—The death of Sir Howard Grubb at Monkstown, County Dublin, on September 17, in his eighty-seventh year, removes one who was famed for his work as a practical optician and astronomical instrument maker. He devoted his life to the improvement of the astronomical telescope, a subject which allowed full scope to his great scientific knowledge combined with rare technical skill. As a mark of appreciation

of his work, the following congratulatory address, signed by eighteen of the leading astronomers of Great Britain, was presented to him in 1926 February.

" On the approach of the eighty-second anniversary of his birthday, we wish to convey to Sir Howard Grubb our hearty good wishes.

" We recall with admiration his devoted application of his resourcefulness and ingenuity to the development of the instrumental equipment of Astronomers through more than sixty years, and we wish to record our grateful sense of the great services rendered by him and his celebrated firm to our science.

" Especially do we recall with pleasure his contribution to the undertaking of the Photographic Survey of the Heavens, including the provision of suitable object glasses, and of the refined clockwork needed for the accurate movement of the telescopes.

" It gives us great pleasure to note that his scientific interests are still maintained, and we hope that they will so continue for many years to come."

Sir Howard was born in Dublin in 1844. He was educated at a private school and at Trinity College, Dublin, where he studied civil engineering. His father, Thomas Grubb, F.R.S., an account of whose life is given in the *Dictionary of National Biography*, besides being engineer to the Bank of Ireland, carried on an engineering and scientific instrument business at Charlemont Bridge Works, Dublin, which he founded early in the nineteenth century. The ingenuity and originality of his designs was well shown in the machines which he constructed for engraving, printing and numbering the notes of the Bank of Ireland. These machines were in use until 1921.

Thomas Grubb's skill in practical optics led to his taking up the construction of astronomical telescopes, and his work acquired a great reputation. In 1835 he constructed, for Armagh Observatory, a 15-inch reflector in which he applied, for the first time, equilibrating levers for supporting the mirror. At his suggestion, Lord Rosse adopted the same system with a little more complication for supporting the specula in his 3-foot and 6-foot reflectors. In 1862 the Government of Victoria requested the Royal Society to give their advice and assistance in obtaining a large reflecting telescope for the southern hemisphere. They recommended that the instrument should be made by Mr. Grubb, and a committee, consisting of the Earl of Rosse, Dr. Romney Robinson and Mr. de la Rue, was appointed to superintend the work. The contract was made about the year 1865, and Howard was withdrawn from Trinity College to assist his father in the design and construction of this telescope, which was finished in 1868. After its completion, the committee appointed by the Royal Society in their report declared it to be a " masterpiece of engineering." The instrument was erected at Melbourne, South Australia, and was, until recently, the largest reflector in the southern hemisphere.

Howard Grubb took over sole control of the works on his father's retirement in 1868, and moved into larger premises in Rathmines, Dublin. In 1870 he completed a 15-inch refractor, which was lent by the Royal Society to Sir William Huggins at Tulse Hill Observatory, and one of the same size, in 1872, was completed for Lord Crawford, Dunecht Observatory. This instrument is now under reconstruction for the Royal Observatory, Edinburgh. In 1875 he completed a $12\frac{1}{4}$-inch refractor for the University

Observatory, Oxford, and in the same year undertook the construction of the 27-inch refractor, with its 42-foot dome, and also three smaller domes, for the Royal Observatory, Vienna. This telescope was erected about 1880, and held the primacy for five years. Dr. H. C. Vogel, in his report on the objective of this telescope in 1883, states: " I have with advantage on splendidly clear evenings in September used a power of 1000 and even of 1500 and perceived the fine details of planetary discs with admirable sharpness. The images of bright stars were of perfect regularity and the central part of the diffraction disc was so remarkably small, that it may be expected that the instrument would also be very suited for observing double stars."

One of Grubb's most important undertakings, and probably one of the most difficult, was the construction of seven of the photographic telescopes for the international survey of the heavens. These instruments have 13-inch objectives with 10-inch guiders. The conditions were exacting, the focal lengths of all the photographic objectives having to be the same within close limits, a very difficult undertaking. Moreover, particular attention had to be paid to the driving mechanism, and it was here that Grubb perfected his system of controlling the movement by an independent pendulum.

The majority of telescopes built by Sir Howard were refractors. In addition to those mentioned he made 15-inch instruments for the Nizamiah Observatory, Hyderabad, for Mississippi, U.S.A., and for Mr. Dunn of Maidenhead (now at Hepple Woodside, Northumberland); 24-inch photographic with 18-inch guiders for Cape Town and for the Radcliffe Observatory, Oxford; the 26-inch " Thompson " for Greenwich; the 26½-inch for Johannesburg; and numerous smaller instruments. Records show that between 1890 and 1914 he made upwards of 90 first-class astronomical objectives from 5 inches to 28 inches aperture. The last named, at Greenwich, is of the " Stokes " type with reversible crown lens.

Among reflecting telescopes may be mentioned the 20-inch for Dr. Isaac Roberts, the 24-inch for Mr. Wilson of Daramona, now at the Mill Hill Observatory of London University, and the 40-inch for Simeis, South Russia.

It is interesting to note that he refigured the mirror of the 36-inch Crossley reflector shortly before it was presented to the Lick Observatory.

He made a 30-inch siderostat for the Smithsonian Institute at Washington, a spectroheliograph for the Madrid Observatory, and a 7-metre solar spectrograph for Poulkovo.

Sir Howard is believed to have been the first to suggest the use of a rising floor in observatories. This was about the year 1880, when he submitted plans for the Lick Observatory. His design for the elevating floor was adopted, with the exception of some details as to the method of working it.

Grubb did not confine his energies to astronomical instruments. In 1900 he patented a novel form of optical gun sight, and developed and perfected the submarine periscope, which he manufactured for the British

Government. During the war the works were turned over to the manufacture of these instruments, and it was in this connection that the factory was removed to St. Albans. In 1925 the business was acquired by the late Sir Charles A. Parsons, when Sir Howard retired from active participation and returned to Dublin. Sir Charles formed a new company under the name of Sir Howard Grubb, Parsons & Co., and built a factory specially to deal with the manufacture of large telescopes, on ground adjoining the Heaton Works of Messrs. C. A. Parsons & Co., Ltd., Newcastle-on-Tyne, who are now the proprietors of the business.

Sir Howard was elected a Fellow of the Royal Society in 1883 and was knighted in 1887. In 1913 he was appointed scientific adviser to the Board of Irish Lights in succession to Sir Robert Ball. He took a great interest in the Royal Dublin Society, with which he had been associated from 1869 and of which he was a governor for many years. He was an honorary member of the Royal Institute of Engineers of Ireland, and he held the honorary degree of Master of Engineering, University of Dublin. He received the Cunningham Gold Medal of the Royal Irish Academy in 1881, and the Boyle Medal of the Royal Dublin Society in 1912.

He married in 1871 Mary Hester, daughter of George Hamilton Walker, M.D., of Louisiana, U.S.A., who predeceased her husband by a few months.

He was elected a Fellow of the Society on 1870 November 11.

C. Y.

G. P. BLACKWOOD HALLOWES, who was born at Penrith, Cumberland, on 1867 April 12, was educated at King William's College, I.O.M. He entered the Surveying branch of the Postal Service and his chief spheres of duty were York (1894–1902), Harrogate (1902–1904), Dublin (1904–1909) and Shrewsbury (1909–1912). He retired, owing to ill-health, in 1912, residing for some time at Kingstown and for the last seven years at Colehill, Wimborne.

At the age of seventeen Hallowes began to take a serious interest in astronomy, and for many years devoted his time to the study of the Moon and, latterly, of variable stars. He was the possessor of a fine 12½-inch Calver reflecting telescope. He was a member of the British Astronomical Association.

In 1893 Hallowes married Lilian Maud Vallance, daughter of the Reverend Lucius Ormsby Cary, Vicar of Brenzett, Kent.

He died on 1931 November 11 in Cornelia Hospital, Poole, of septicæmia, following minor injuries received in a motor accident on October 27 while conveying electors to the poll during the General Election. Mrs. Hallowes, who was also in the car, died of her injuries two days later. Mr. Hallowes is survived by two sons and a daughter.

He was elected a Fellow of the Society on 1891 February 13.

THOMAS LAING was born near Keith in 1851 September. His early life was full of hardships, for necessity forced him at the age of ten to earn his own living. Despite these early years of toil he devoted

the brief opportunities of leisure to private reading, and at the age of twenty-three he went to school for a year, afterwards entering Aberdeen University, where he passed in all the subjects for the M.A. degree except Mathematics and Natural Philosophy. He was then admitted a divinity student, and, on the completion of his theological studies, served as assistant in several charges before being ordained Minister of the United Free Church at Auchindoir. After thirty-one years of devoted service there he retired to Bieldside, Aberdeen. His indomitable spirit, which knew no defeat, urged him to resume the study of Mathematics and Natural Philosophy. Success came to him, and he received the degree of M.A. at the age of seventy-three. All his life he was a keen student of astronomy, and at Auchindoir and elsewhere he gave lectures on the subject which were much appreciated. In 1907 he married Jane Ironside, daughter of James Ironside of Lumsden, Aberdeenshire, by whom he is survived. He died at Bieldside on 1930 December 10.

He was elected a Fellow of the Society on 1914 May 8.

ADOLPH FRIEDRICH LINDEMANN was born on 1846 May 13 at Langenberg in the Palatinate. From his earliest boyhood he displayed a keen interest in science. He often said that one of the proudest days of his life was when, at the age of fourteen, he set a star in his home-made equatorial and found it exactly upon the cross-wires. His intention was to become an explorer; to fit himself for this and gain experience he undertook, after reading engineering at Nüremberg, the reduction of Neumayer's Australian observations. He then proceeded to study instrument design in the works of Ertel at Munich, for he held that the ability to use and repair any scientific instrument would be an invaluable asset in his chosen profession. While at Munich he unfortunately suffered a severe attack of typhoid fever. On his recovery he found he could no longer support extremes of climate as before and was obliged to forego his early ambitions.

The electrical industry was at that time coming into being. Lindemann took a position in the firm of Siemens Bros. in Woolwich, which was then mainly concerned with cable-making. Within a year he was placed at the head of this department and was responsible for constructing and laying the first cable connecting Ireland and the United States, the only one from that period still in use.

A year later, after a scientific lecture in Pirmasens, he was half-jokingly challenged to supply the town with water instead of finding fossils. As Pirmasens lies some seven hundred feet above the level of the valley, it required some courage to accept this challenge. Despite the difficulties of pumping water to this height, he carried the work through successfully, financing it in London and acting entirely as his own designer, engineer and architect. The waterworks were a complete success and the town in the course of forty years trebled its number of inhabitants and developed into a considerable industrial centre.

In 1884 Lindemann married and settled at Sidmouth. He bought a small observatory which he erected there, and spent much of his time

designing and perfecting accessories. A most ingenious chronograph dates from this period, as also a revolving eyepiece, the first of its kind to be constructed. Each ocular was electrically heated to prevent fogging, and fell automatically into focus. In these years also he spent much of his time in working out the design of a novel form of telescope. In principle it has something in common with the Coudé construction, of which, however, he only heard later, though it avoids most of the difficulties of this type, more especially the loss of field of view. Two plane mirrors at 45° to the polar axis, which can be rotated in declination and right ascension, enable the light from any star to be reflected down the polar axis in which the telescope proper is permanently fixed. Whilst some light is lost in the two reflections, this is set off by the advantage of having a steady telescope in stable conditions and also by the economy of having no dome, moving floor or similar paraphernalia. The tower telescopes at Mount Wilson attain the same result in a similar manner.

A theoretical paper dealt with Halley's comet. Two methods, based upon the effect of light-pressure, were put forward which enabled an estimate of mass to be made. In 1915 a paper was published in which it was shown that it was possible to photograph bright stars in broad daylight. Had the classical equation for scattering been strictly true, one would have been able to photograph stars so close to the Sun that it would have been possible to test by this means Einstein's formula for the deflection of light without waiting for an eclipse. Unfortunately this was not successful.

In 1919 an instrument was described for measuring photo-electrically stellar magnitudes. It consisted in essentials of an airtight box in which the photo-electric cell was mounted rigidly fixed to a new form of electrometer of small capacity, whose sensitivity and zero were independent of position. A mirror which could be swung into place at 45° enabled one to observe the star one was examining and make certain it was in the centre of the field, from which one could exclude other light by means of an iris diaphragm. Various coloured filters could be interposed to ascertain the colour-index, and an electrically controlled shutter allowed the time during which the light fell on the cell, *i.e.* during which the electrometer was charged, to be exactly controlled. The electrometer consisted of a platinised glass cross-fibre, some 30 μ thick, which was suspended in the centre of a silica torsion thread about 3 μ thick, fixed under tension to a silica frame ; electricity flowing from the cell to the fibre caused it to move in the field of small quadrants charged to a fixed potential. The cross-fibre was carefully balanced so that the zero of the electrometer, as well as its sensitivity, was independent of the position. The whole apparatus weighed only a few pounds, so that it could be substituted for the eyepiece in any telescope. This instrument shows all the old genius of design and was the forerunner of the Lindemann electrometer now so widely used.

All these pieces of apparatus were made in his own workshop with his own hands. He was never so happy as when he was at his lathe, turning with exquisite precision some delicate part, or at his desk, inventing some ingenious device to circumvent a difficulty. He scarcely ever read a

novel, but any form of science, biological or mathematical, fascinated him. Right up to the end his interest never flagged. He visited the Royal Observatory in 1931 June and was anxious to know whether variations in the Earth's magnetic field might not affect the accurate timekeeping of the invar pendulums. In July he flew, as was his custom despite his eighty-five years, to Ems, where he took the cure. Unfortunately, on his return he caught bronchitis to which he succumbed on 1931 August 25.

Lindemann had one daughter and three sons, one of whom is F. A. Lindemann, Professor of Experimental Philosophy at Oxford University.

Lindemann was elected a Fellow of the Society on 1873 February 14, and attended regularly at the meetings whenever he was in London. The memory of his deep interest in the welfare of the Society is perpetuated by the large legacy which he bequeathed to the general funds of the Society. The Prussian Academy of Sciences conferred upon him the Leibnitz medal, and one of the minor planets was named after him in recognition of his services to astronomy.

CHARLES JAMES MERFIELD.—The tragic death on 1931 January 23 of Charles James Merfield, Chief Assistant Astronomer at the Melbourne Observatory, as a result of injuries received in a motor accident, came as a severe shock to all who knew him. Sympathy was heightened by the fact that his younger son, Theon, was driving the car at the time of the accident, and for some months after lay himself in a very critical condition. In the best of health, Mr. Merfield left the observatory the day before his death with the intention of journeying to Stawell to supervise the erection there of a very fine sundial which he had designed as a memorial to the late Mr. Simmons, an old friend and a prominent personality in Stawell.

Mr. Merfield leaves a widow and an adult family of two sons and a daughter. At the present time both sons are connected with the Melbourne University. The daughter is attached to the teaching staff of the Melbourne Church of England Girls' Grammar School.

Mr. Merfield was born at Ararat, near the town of Stawell, in the State of Victoria, Australia, on 1866 April 28. He received his early education at the Stawell Grammar School. Later he specialised in mathematics, surveying and civil engineering. For a number of years he was employed by the Government in the construction of new railway lines through the then virgin territory of Victoria. He not only supervised the laying out of a number of the more important lines in that state, but about 1892, after his marriage with Miss Margaret Ada Bradley, a descendant of an old Gloucestershire family, he went to New South Wales where he was engaged upon similar work. According to Mr. Deane, then Chief of the New South Wales Railways, " Merfield's knowledge of higher mathematics was made considerable use of by the Department, generally when any intricate problem had to be solved. A monument to his labours in this direction may be found in the formula and tables for laying out transition curves and springs, which data are now used universally in railway construction work."

Throughout the whole of this time he was greatly interested in astronomy,

and was soon recognised as one of the ablest computers in the country. His activity may be best judged by reference to the astronomical literature of that period, one notable paper, the " Definite Orbit Elements of Comet 1901, I," having the distinction of forming Part 2 of Number 4 of the *Astronomische Abhandlungen als Erganzungshefte zu den Astronomischen Nachrichten*, edited then by Professor Dr. H. Kreutz.

After settling in New South Wales, Mr. Merfield became a close friend of the late Mr. John Tebbutt, F.R.S., F.R.A.S., and for many years collaborated with him. The correspondence, almost a weekly letter, which passed between these two amateur astronomers is extremely interesting and throws considerable light on the history of astronomy in Australia from the inauguration of the Commonwealth up to the time of Mr. Tebbutt's death. Like Mr. Tebbutt, he not only contributed to the astronomical publications of the older world, but was also the author of numerous articles in the current newspapers. Subsequently he was induced to write regularly, and the astronomical column became quite a feature and was widely appreciated by the general public. He was unquestionably the Australian authority on eclipses, and prepared all the local data. These were generally published in the form of pamphlets with large folder maps.

On several occasions he was temporarily employed at the Sydney Observatory, when the staff was depleted through illness or other causes, but in 1904 he was permanently transferred from the Railway Department to the Government Observatory. On his appointment it seems that he disposed of his private observatory, which consisted of a 10-inch reflector, a 6-inch refractor, a fine transit circle by Troughton & Simms, besides clocks and other equipment.

Merfield published several papers in the *Monthly Notices* and *A.N.* on the perturbations of minor planets and on the orbital elements of various comets. In 1908 he became a member of the Lick Observatory eclipse expedition to Flint Island, where he secured some very fine spectrograms of the corona and chromosphere. Also he accompanied Mr. Baracchi to the Vau Vau eclipse, and was a member of other Australian expeditions.

Apart from his connection with the Society, of which he was a life Fellow, Merfield was at one time a member of the B.A.A. For two years, 1906–1907, he was President of the local branch of the B.A.A. in New South Wales. Also he took an active interest in the Royal Society of N.S.W. He was a member of the Astronomical Committee of the Australian National Research Council, and was responsible for the formation of the Astronomical Society of Victoria, being its first President, which position he filled ably for several years. In professional circles he was keenly interested in the conditions governing salaries and other matters, and for some time was President of the Victorian State Service Professional Association.

In his later years he led a rather sedentary life, hoping on his official retirement from the Melbourne Observatory in 1931 April to publish the results of those researches on which he had so ardently laboured. It is believed that his unpublished manuscripts, and also his extensive astronomical library, were bequeathed to his elder son.

No description of Mr. Merfield's work would be complete without mention of the *Jewish Calendar*, the *Tide Tables* and *Calendar of Astronomical Phenomena* which he compiled, at least a year or two in advance, for the last thirty years.

His outstanding hobby apart from his private astronomical pursuits was amateur photography. His photographs, some of which appear in the well-known *Photograms of the Year* secured international recognition.

He was elected a Fellow of the Society on 1896 January 10.

GUSTAVUS WILLIAM NICOLLS, the eldest son of Colonel Oliver Nicolls, 2nd Foot, was born at Athlone, Ireland, on 1848 February 28. For a time he was a stockbroker in Rio de Janeiro, and later he was engaged in banking in South America and London. In his earlier years he took an active interest in founding astronomical societies at Pernambuco and Rio de Janeiro.

He died at Southampton on 1931 August 17, and is survived by one daughter, the wife of Colonel Sir Edwin Perkins, C.B.E., D.L., J.P. He had three sons, of whom one died in infancy; the second, who was in the Indian Educational Service, died in 1912; and the third, who was a banker, died in Belgium in 1923.

He was elected a Fellow of the Society on 1887 May 13.

Sir CHARLES PARSONS will always be remembered as the greatest engineer since the time of James Watt in the production of power from steam. His genius and perseverance have made the steam turbine the generator of electricity in modern power stations, and the means of propulsion of the largest and fastest ships.

Charles Algernon Parsons, the youngest son of the third Earl of Rosse, was born at Birr Castle, Parsonstown, on 1854 June 12. The famous 6-foot speculum had been completed by his father in 1845, and observations of nebulæ were carried on assiduously by him, and later by his eldest son. In 1865 R. S. Ball, later Sir Robert Ball, was appointed assistant astronomer and tutor to his sons. The mechanical instincts of the boys were shown by the construction of a steam-driven motor-car which reached a speed of 10 miles an hour on the road, and no doubt their tutor gave them adequate instruction in mathematics. In 1873 Parsons obtained a scholarship at St. John's College, Cambridge, and was eleventh wrangler in the Mathematical Tripos of 1876. He then became a pupil in the Elswick works, where he invented a four-cylinder rotary steam-engine. After leaving Elswick he was for a time with Messrs. Kitson of Leeds, and in 1883 became a partner in the firm of Clarke, Chapman & Co. of Gateshead. Here he made his first steam turbine of 4 horse-power, coupled to a small dynamo with armature less than 3 inches, which revolved at the great speed of 18,000 revolutions per minute. The design of the dynamo was as great a feat as that of the steam turbine. The efficiency in steam consumption and the size were rapidly increased, and the dynamo soon came into use for electric lighting. In 1888 a 32-kilowatt machine, running at

8000 revolutions per minute, with 100 lb. per square inch pressure in saturated steam, and non-condensing, gave a consumption of 51 lb. per kilowatt-hour.

In 1889 Parsons left Clarke, Chapman & Co., and set up the Heaton Works at Newcastle-on-Tyne, to manufacture steam turbines and other machinery. As Clarke, Chapman & Co. held the original patents, Parsons had to alter the design of the turbines, but in 1894 was able to buy them back, and reverted to his original design with the flow of steam parallel to the axis. Essentially the original model of the 4-kilowatt turbine of 1884 has been followed in the modern steam turbines of 50,000 kilowatts.

In 1894 Parsons turned his attention to the application of the steam turbine to the propulsion of ships. Propellers of ships are slow-turning, while the steam turbine revolves at a high speed. When the propeller revolved rapidly, difficulties of " cavitation " occurred. The *Turbinia* was originally built with one propeller, and attained a speed of not more than 20 knots. For one turbine three in series were substituted, and on each of the three shafts there were three propellers, and in 1897 a speed of 34 knots was obtained. This was produced at the Jubilee Naval Review, and in defiance of patrol boats the *Turbinia* ran between the lines of the ships at this unprecedented speed. The after portion of the *Turbinia* is now in the Science Museum.

The Admiralty soon adopted the steam turbine, first for the destroyers *Viper* and *Cobra*, and afterwards the cruiser *Amethyst*. The result of a comparison with the sister ship *Topaz*, fitted with reciprocating engines, were so satisfactory that the *Dreadnought* was fitted with turbines. This has been followed as a regular procedure in British and other navies. In the mercantile marine, turbines were first employed in a passenger steamer on the Clyde, next in the Calais–Dover service, and in 1907 the Cunard Line adopted them in the *Mauretania* and *Lusitania*.

Parsons next faced the difficulties of adapting the fast-moving turbine to the slow-moving propeller of the ordinary steamer. In 1912, by experiments on the cargo steamer *Vespasian*, he devised suitable gearing by which the propeller could be driven at its usual speed, with a gain of 20 per cent. efficiency on reciprocating engines. In 1926 he made still further advance by showing that increased efficiency could be produced by the use of steam at a pressure of 550 lb. per square inch.

Parsons grew up with an interest in optical work, and as early as 1887 greatly improved the methods of making searchlight reflectors. At the Heaton works he constructed large parabolic reflectors up to 6 or 7 feet in diameter. This led to the investigation of the most suitable glass for withstanding sudden changes of temperature, resulting in a boro-silicate glass for these mirrors.

In 1921 January he acquired a large interest in the optical firm of Ross, Ltd., and became chairman of the company. His engineering genius led to improvements in the method of grinding glass, and his aim throughout was the production of the most perfect instruments concurrent with the lowest cost of production. He always pressed forward in research, and,

as a member of the firm remarks, one of his favourite phrases in discussing any construction or process was : " Have you tried it?"

In 1921 July he made a further venture by taking over the works of the Derby Crown Glass Company. The shortage of optical glass during the War had led to the formation of this firm by Wood Brothers of Barnsley. In 1921 there was danger that the works might be closed. Parsons saw how necessary was the production of different kinds of optical glass for the manufacture of binoculars, prisms and large discs for telescope objectives, and definitely shouldered this burden. He accepted an order from Sir Howard Grubb, Sons, for the manufacture of flint and crown discs for the 27-inch telescope of the Union Observatory, Johannesburg, and succeeded in delivering them in the short time of nine months. He proceeded by experiment and research in many directions to facilitate the production of large discs of glass. Improved methods of stirring were introduced to obtain greater homogeneity in the glass, and the breakage of pots was checked by better methods of heating the furnaces. The control of the process of annealing presented many difficulties. Discs up to 42 inches can now be successfully produced.

In 1925 Parsons re-established at Heaton the famous firm of telescope makers, headed by his old friend Sir Howard Grubb, under the title of Sir Howard Grubb, Parsons & Co. Here he constructed large equatorial reflecting telescopes for Stockholm and Edinburgh. He obtained an order for the 74-inch reflecting telescope of Toronto, which is now being made.

There was in Parsons a remarkable versatility. His connection with high temperatures and pressures led him to pursue researches in the production of diamonds. In 1888, by means of an 80-ton press, he tried the effect of pressure of 30 tons on electrically heated carbon. Twenty years later he pursued these investigations with still higher pressures, with the presses in strong houses to guard against the danger of explosions. Having exhausted the possibilities of steady pressures, he obtained momentary pressures by firing steel bullets into a hole of the same diameter as the bore. These reached 5000 tons per square inch, or something like the pressure at the centre of the Earth. He demonstrated that diamonds were not produced by great pressures, and by further experiments on the explosion of acetylene and oxygen, where a temperature of 15,000–17,000 degrees C. was attained, concluded that a high temperature was not a necessary factor in their production. The question of high pressures also arose in connection with the erosion of propellers, for which a committee of investigation was formed during the War, on which Parsons served. It appeared that pressures to the amount of 20,000 lb. to the square inch might be produced over minute vacuous cavities, and intense blows were experienced over small parts of the blades. In 1904, when President of the Engineering Section of the British Association, he made the suggestion of sinking a shaft or bore-hole to a depth of 12 miles, with a view to research on the constitution of the Earth's crust. He considered the engineering difficulties, and concluded that an outlay of £5,000,000 would be required, and the time occupied eighty years. In 1919, when President of the British Association, he concluded that the time

might be reduced to thirty years, in consequence of the improvements in drilling machinery.

Those who had the privilege of meeting Sir Charles Parsons were struck by his quiet and modest, and even slightly hesitating, manner. If matters of detail, which could be easily arranged, were under discussion he took no apparent interest; but when a difficulty arose his eyes twinkled, and he soon showed how the question should be dealt with. Many have found in him a wise helper and a good friend.

Sir Charles Parsons was made K.C.B. in 1911, and received the Order of Merit in 1927. He was awarded the Rumford and Copley Medals of the Royal Society, the Albert Medal of the Royal Society of Arts, and the Faraday and Kelvin Medals of the Institution of Electrical Engineers. During the War he served on the Advisory Council of the Department of Scientific and Industrial Research and on the Fuel Research Board. He was a generous benefactor of the Royal Institution and the British Association, and in 1922 gave to the Royal Astronomical Society £2500 War Stock in memory of his father, the third Earl of Rosse.

He married in 1883 Katherine, daughter of Mr. W. B. Bethel of Rise Park, Yorkshire. Lady Parsons is founder of the Women's Engineering Society. Their only son was killed in action in 1918; their only daughter, who had been through the Engineering School at Cambridge, served in the Training Department of the Ministry of Munitions. Sir Charles died on 1931 February 11, while on a voyage to the West Indies. His body was brought to England, and buried at Kirkwhelpington in Northumberland. A Memorial Service was held in Westminster Abbey.

He was elected a Fellow of the Society on 1917 January 12.

F. W. D.

SOLON I. BAILEY, Phillips Professor of Astronomy, Emeritus, at Harvard University, a member of the staff of Harvard Observatory for forty-four years, and Acting Director from 1919 to 1921, died on 1931 June 5 at his summer home near Boston.

He was born on 1854 December 29 at Lisbon, New Hampshire, and was descended from the sturdy original settlers of New England. After graduating from Boston University and teaching several years at Tilton Academy, he moved in 1887 to Cambridge, Mass., where, under Professor Edward C. Pickering, then Director of the Harvard Observatory, he took up visual observations of stellar magnitudes with the meridian photometer.

However, his life work in astronomy was destined to lie in other channels, for it was at this critical time that, after years of trial, the photography of the sky was beginning to replace older methods of research. It was at this time also that the Boyden fund of $238,000 became available for establishing a station at a high elevation. Professor Pickering selected Bailey to carry out this bequest somewhere on the high plateau of Peru, where also the whole southern sky could be observed. For this purpose Professor Bailey, with his wife and small son Irving, sailed southward from San

Francisco after observing the total solar eclipse of 1889 January 1, at Willows, California.

His descriptions of this journey and of the search for a location from " Lima to as far south as the deserts of Chile near Valparaiso " form interesting chapters in the *Harvard Annals*. During a year passed on " Mt. Harvard " near Chosica and several months on the desert of Atacama, where the sky was exceptionally clear, Bailey completed visual observations of the magnitudes of 7922 stars, thus extending the Harvard Photometry to the South Pole.

A site near Arequipa at an elevation of 8000 feet was finally selected, and there the Boyden station remained in active service for thirty-seven years, until in 1927 it was removed to its present location near Bloemfontein, South Africa.

In 1893 Professor Bailey commenced to photograph the dense globular clusters with the 13-inch Boyden telescope. A careful study of these photographs soon revealed that large numbers of variable stars existed in certain rich clusters, such as M3, M5 and ω Centauri. A few variable stars in clusters had been found previously, but, as Professor Pickering stated, " the real work of discovery, observation and discussion of variable stars in clusters was done by Bailey." As early as 1898, in certain globular clusters, whose area comprises about one thirty-thousandth part of the sky, he had found 509 variable stars, or nearly as many as were then known in all other portions of the sky.

The magnitudes, elements, and light curves of the variables in ω Centauri, M3, M5 and M15 are given in vols. 38 and 78 of the *Harvard Annals*. The two most important characteristics of " cluster variables," as Bailey named them, found by him from this investigation, were that the period is around one-half of a day for the great majority of these stars, and that the median magnitude of all such variables in any cluster is uniform, no matter what is the length of the period.

When, a few years later, the relation between period and luminosity of Cepheid variables became known, Bailey's pioneer and accurate investigation of the cluster variables formed one of the foundation stones for Dr. Shapley's study of the parallaxes of the clusters and of the dimensions of the universe.

Since there was a dearth of any reliable records of weather in Peru, regular meteorological observations were organized and carried out from 1891 to 1927. By long, arduous, and sometimes dangerous journeys, mostly on horseback, Bailey established a chain of meteorological stations from Mollendo on the Pacific Ocean to Lake Titicaca and beyond to Santa Ana in the Urubamba Valley. The highest point was on the summit of El Misti, the nearly extinct volcano, towering 19,200 feet over Arequipa and the Boyden station.

Bailey's description of this cone-shaped volcano, El Misti, and the story of the establishment of the station by the construction of a mule path to the summit are contained in the first chapter of vol. 39 of the *Annals*. Continually baffled and weakened by mountain sickness, the ascent was finally

made possible on mule-back and thus the highest meteorological station in the world was maintained for six years.

During the ten years altogether spent in Peru by Professor Bailey, he learned to know and to love the country and its people. Although of a reserved and somewhat diffident nature, in Arequipa he made friends easily and seemed to understand thoroughly all classes of the people, who regarded him as an ideal American gentleman. " What a charming place in which to pass old age," he once remarked of Arequipa—" no snow, little rain, no storms, nor extremes of heat and cold." Although never given to exploiting his own experiences, he could talk delightfully of many of the rare sights of that land, such as the crescent-shaped sand-dunes of La Joya, of the remarkable Inca fortress at Sacsahuaman, or of his unique journey over the Andes to the Plain of the Amazon.

Besides the cluster variables, Bailey attacked various other problems with skill and accuracy. His measures of the light of Eros when the little planet was far south at the opposition of 1903 were notable, and the period $0^{d}.2196$ which he derived for the variation was so good that, if two ciphers are added to it, the observations of 1931 are represented to the fraction of a second.

He was perhaps the first to recognize the importance of a photographic study of extra-galactic nebulæ, and under his direction nearly 3000 new nebulæ were found before 1908 on the Bruce photographs. He had great faith in the Bruce 24-inch telescope, with its great light-gathering power and large field of view, and, when in Peru, he personally took charge of this instrument, securing many plates of the highest quality. During his last visit to Arequipa, in 1922 and 1923, he made numerous long exposures, sometimes of ten hours, for a study of stellar distribution. In *Harvard Circular*, No. 242, he presented a " Comparison of a Milky Way Field with one at the South Galactic Pole," discussing stars to the nineteenth magnitude. Interesting results were obtained from such counts, as, for instance, that while for stars of magnitude 9·5 and brighter the number in the galactic area is only twice that at the Pole, the ratio increases rapidly for the fainter stars until the maximum is reached at the seventeenth magnitude, when the number in the galaxy is 160 times that at the Pole.

When, in 1925, Professor Bailey's retirement came, at the age of seventy, he did not wish to be idle, and at Dr. Shapley's request he undertook to prepare a history of the Harvard Observatory, a task which had also been planned for him years earlier by Professor Pickering. The book, which is Harvard Monograph No. 4, is entitled *The History and Work of Harvard Observatory*, 1839 to 1927. In it, the origin, the development, the problems and the personnel of the observatory are discussed with unbiassed judgment. This book had just been printed and his last volume of *Peruvian Meteorology* was in the press at the time of his fatal illness.

Besides being an Associate of the Royal Astronomical Society, Bailey was a Fellow of the American Association for the Advancement of Science, a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the Astronomische Gesellschaft and of the International

Astronomical Union, of which he was, in 1922, President of the Variable Star Commission.

In 1923 he was made an honorary Doctor of Science and honorary Professor of Astronomy in the old University of St. Augustin, Arequipa.

Professor Bailey was possessed of a rare personality, combining rugged strength with the charm of suave and gentle manners. Because of his sympathetic understanding of life's problems, and his courteous consideration of others, he was held in the highest regard by all, whether acquaintances, friends, or associates.

He is survived by his widow, Ruth E. Bailey, and their son, Irving W. Bailey, Professor of Plant Anatomy in Harvard University.

He was elected an Associate of the Society on 1915 June 11.

A. J. C.

ALBERT ABRAHAM MICHELSON was born at Strelno in Germany on 1852 December 19. His parents migrated to the United States soon after his birth, and his early education was in San Francisco. He graduated at the Naval Academy, and became an instructor there until 1879. He then had a further period of study at universities in Germany and France. He returned to become Professor of Physics at the Case School, Cleveland (1883–89), afterwards at Clark University (1889–92), and finally at the University of Chicago. He is outstanding as a man who could bring big ideas to fruition. Of especial importance are his unrivalled determinations of the velocity of light and his development of the interferometer for use in the most delicate types of measurement. The latter instrument was used in his two most sensational achievements—the Michelson-Morley experiment and the measurement of the angular diameter of a star. Among the many distinctions conferred on him may be mentioned the Copley Medal of the Royal Society (1907), the Nobel Prize (1907), and the Gold Medal of the Royal Astronomical Society (1923).

The use of interference fringes for determining the angular diameter of a star had been tried unsuccessfully by Stéphan as early as 1874. Michelson made the first fruitful application of the method in 1891, measuring the diameters of the four satellites of Jupiter; his results were afterwards closely confirmed by Hamy at Paris, who followed his method, but nothing more of the kind seems to have been attempted until 1919. Michelson then took up the method again with characteristic energy, using first the 40-inch telescope at Yerkes and afterwards the 60-inch and 100-inch at Mt. Wilson. His interferometer for the last-named instrument was a 20-foot girder with mirrors attached, placed across the aperture of the telescope. With the co-operation of Pease and Anderson he soon reached success. On 1920 December 13 the angular diameter of a star (Betelgeuse) was measured accurately for the first time.

The principle of Michelson's method may be briefly explained. That which is seen with a telescope is partly a facsimile of the object viewed and partly an interference pattern determined by the size and shape of the aperture of the telescope. According to the relative prominence of the two

components, we may say either that the interference pattern blurs the true image or that the true image blurs the interference pattern. Regarded in the latter way, the amount of blurring is an indication of the size of the true image. Michelson's problem, therefore, was to provide an interference pattern with detail sufficiently fine to be perceptibly blurred even by the minute true image of a star. Such a pattern was produced by combining the light from two widely separated apertures whose distance apart could be adjusted up to 20 feet. It was found that at 10 feet separation the fine interference fringes seen in the images of ordinary stars were completely blurred out in Betelgeuse; from this an angular diameter of 0″·045 was deduced.

It may be of interest to recall that the method of measuring double stars by the aid of diffraction images produced by combinations of slit apertures is traceable to Michelson. This was first employed in 1895 by Schwarzschild, who states that the idea came to him through reading Michelson's paper. Michelson's more elaborate interferometer also made a contribution of great importance to double star astronomy. As a step towards the more ambitious attempt to measure stellar diameters it was applied to the determination of the orbit of Capella. This resulted in a very good determination of the mass of Capella; and since there were (and still are) no other *giant* stars with adequately determined data, Capella became the standard star for astrophysical purposes.

The Michelson-Morley experiment was performed in 1887, an earlier attempt having been made by Michelson alone in 1881. This is perhaps the most important link in the chain of experiments and theories regarding the effect of the Earth's motion on the apparent propagation of light, which extended from Bradley's discovery of aberration in 1727 to Einstein's theory of relativity in 1905. The point to be tested was whether the Earth in its orbital motion passes through the luminiferous æther without disturbing it, so that at any station on the Earth the æther is slipping past the observer and his apparatus borne along by the planet. To the astronomer at least there could be no serious doubt that this was the fact. So far as accuracy is concerned, astronomical measurements of aberration give a much more delicate test than any physical experiment—even the Michelson-Morley experiment. Moreover, the fact that aberration at a mountain observatory is the same as at sea-level shows that there is no perceptible differential æther-drift at different levels. The only escape from this conclusion was a hypothesis originated by Stokes ; but this was little more than a mathematical curiosity, and was too full of objections to be developed very seriously. On the other hand, the observations with Airy's water-telescope, and experiments by Arago and Fizeau on the convection of light-waves by moving glass and water, seemed to indicate that the motion of solids was not wholly without influence on the æther. Perhaps the biggest difficulty of all was one of sentiment. How could the solid Earth push its way through the luminiferous æther without displacing it? This difficulty was not finally removed until 1912, when Rutherford and Bohr introduced the solar-system type of atom through which an æther could slip as easily as through interplanetary space.

Had the Michelson-Morley experiment been "successful," it would not merely have confirmed the drift of the æther past the Earth but would have measured the absolute motion of the solar system through space, *i.e.* the motion referred to the supposed universal standard of rest provided by the æther. It would thus have revealed something more than astronomical aberration could reveal. I am not sure that Michelson was ever really convinced that his epoch-making work was not a failure ; for he had small sympathy with the revolutionary developments of theory which ultimately sprang from it. The experiment gave a null result ; apparently the æther at the Earth's surface was carried along with the Earth, in flat contradiction to the evidence of astronomical aberration. Previous experiments on æther-drift had been first-order experiments depending on effects proportional to v/c ; Michelson's was a second-order experiment designed to catch terms 10,000 times smaller depending on v^2/c^2. It seemed certain that the velocity v through æther, which had already acquired a reputation for elusiveness, would not escape this time. Michelson has told me himself that the null result was a very great disappointment to him. This failure to detect æther-drift, and the contradictory state in which it left the theory, was the gateway to a great development of physics, chiefly by Lorentz and Larmor and afterwards by Einstein. Michelson later performed one of his characteristic experiments on a vast scale to detect the effect of the rotation of the Earth on the propagation of light by sending beams in opposite directions round a large circuit. As a *tour de force* the experiment was successful ; but since both non-relativists and relativists predicted the same result it did not settle any disputed point of theory.

The velocity of light was Michelson's lifelong study. His first standard determination in 1880 was a great advance on the previous determination by Foucault. In 1926 he obtained the value 299796 ± 4 km. per sec. which is at present in general use. At the time of his death he was engaged in a further attempt to realise his cherished ambition to fix the value of this constant to within one kilometre per second.

He married in 1899, and had one son and three daughters. His death occurred on 1931 May 9. He was elected an Associate of the Society on 1894 November 9. A. S. E.

ALFRED WOLFER, who died on 1931 October 8, was for fifty years associated with the Federal Observatory at Zürich. Throughout that time he worked specially on sunspots—a subject which had been taken up by his predecessor, Rudolf L. Wolf, the first director of the observatory. The activity of the observatory in discussing the frequency of sunspots from records back to 1610, and in collecting later data, led to it being chosen as the centre for sunspot data by the International Astronomical Union.

Wolfer was born at Schönenberg, near Zürich, on 1854 January 27. His early circumstances were not favourable to a scientific career, but by perseverance he succeeded in entering the Technical High School at Zürich. After studying mathematics he took his diploma for an essay on the division errors of the transit circle. He found no suitable opening, and worked for

a year as a voluntary assistant at the observatory till a vacancy occurred. His astronomical work at first included meridian circle observations and planetary observations with the refractor. He also discussed meteorological observations. Although he was for most of his life very interested in meteorology and was an active member of the Swiss Meteorological Commission, he refused an appointment in the meteorological observatory at Pawlowsk. As Wolf, the Director of the Zürich Observatory, became more and more occupied with his discussions, he left the practical work of the observatory to Wolfer, who finally succeeded him as Director in 1893.

Wolfer obtained additional support for the observatory—a second assistant and new instruments. The latter included a 13-inch telescope, as compared with the $6\frac{1}{2}$-inch which had been the largest telescope of the observatory for about fifty years, and a spectrohelioscope. The publications of Zürich Observatory are concerned principally with observations of the Sun and with statistical work on the frequency of sunspots and their connection with terrestrial magnetism. During Wolfer's directorate there were issued 31 numbers of the *Astronomische Mitteilungen* and 5 volumes of publications. The latter give heliographic charts of all the phenomena of the Sun's photosphere for all rotations for an 11-year period. Work by Wolfer's pupils on the proper motions of spots are also included in the volumes.

Although Wolfer is best known to astronomers for his work on sunspots, he did valuable teaching and administrative work at the university. He took an active part in the Swiss Geodetic Commission and, as already mentioned, in the Swiss Meteorological Commission. He was naturally a member of the International Commission on Terrestrial Magnetism. Through these Commissions he became widely known to scientific colleagues throughout the world. His enthusiasm took him back regularly to the observatory to observe after his retirement in 1926, and later, when this was too great a strain for him, he made observations at his own home. He corresponded regularly with those interested in his work, and his friendly presence will be missed from international meetings of astronomers.

He was elected an Associate of the Society on 1913 June 13.

J. J.

PROCEEDINGS OF OBSERVATORIES

The following reports of the proceedings of observatories during the past year have been received from the respective Directors, who are alone responsible for them.

Royal Observatory, Greenwich
(*Director, Sir Frank Dyson, K.B.E., Astronomer Royal*)

Transit Circle.—The number of transits observed during the year was 9435, including 122 of the Sun and 74 of the Moon.

The observations made over the period 1922 January 1 to 1930 December 31 have been reduced to 1925·0 and ledgered. Mean positions for every star have been determined, and the results will be published in two parts, viz., (1) fundamental stars, and (2) zone stars between declinations $+32°$ and $+64°$.

A discussion of the proper motions of the stars in this catalogue is now in progress.

The observing programme on the third list of reference stars for Eros yielded 107 observations of 19 fundamental stars and 116 observations of 37 comparison stars.

A correction of $-0^s·051$ to Newcomb's equinox was derived from a discussion of the observations of the Sun in the years 1922–1930.

Cookson Floating Zenith Telescope.—During the year 245 plates were obtained for determination of variation of latitude, and 8 for determination of scale. The numbers of plates obtained in the different months were:—

January—18	May—26	September—21
February—23	June—19	October—36
March—20	July—19	November—22
April—11	August—16	December—14

A new measuring micrometer was purchased from Messrs. Adam Hilger, Ltd., in April, and will be used to measure all the plates taken in 1931.

28-*inch Refractor.*—During the year 314 measures of 218 double stars were secured. Arranged according to separation they are :—

$<0''·5$	69	observations
$0''·5 - 1''·0$	75	,,
$1''·0 - 2''·0$	102	,,
$>2''·0$	68	,,

26-*inch Refractor.*—The work on stellar parallaxes has been continued, and during the year 1034 plates suitable for measurement have been secured. In addition to these, 59 plates have been rejected for various causes. 947 plates have been measured. The parallaxes of 33 stars have been published

in the *Monthly Notices* for 1931 November. In 1931 January the instrument was devoted to the observation of Eros, and 59 plates suitable for measurement were obtained on 9 nights.

30-inch Reflector.—With the 30-inch reflector the work on colour temperatures of stars has been continued. Attention has been concentrated on the comparison between the " standard stars " and a laboratory source of known temperature. A considerable amount of experimental work has been carried out under laboratory conditions, and as a result the use of the carbon arc as an intermediary has been abandoned.

The stars are now compared directly with a Kodak standard acetylene burner, which provides a convenient standard at a nominal colour temperature of 2360° K. In comparing the stars with this source a colour filter is inserted in the beam from the burner, and the transmissions of this filter at the wave-lengths used in the measurements are determined in the laboratory.

The stars are those comprised in the Greenwich standard system. On each plate are photographed the spectra of:—

(1) a standard star near the zenith ;
(2) two standard stars at zenith distances 50° to 60° east and west of the meridian;
(3) the screened acetylene flame; and
(4) an accurate light-intensity scale.

The observed differences of gradient between (1) and (2), when compared with the true differences from the standard list, give a determination of the relative atmospheric extinction. This, when applied to the observed comparison between (1) and (3), gives the colour temperature of (1). The colour temperature T_0 of the zero of the standard system is then deduced by the application of the relative gradient of the standard star used. Each plate thus gives a determination of T_0. Twenty-one such plates of good quality have been obtained on 14 nights.

The acetylene burner is mounted on the roof of the Octagon Room, 600 feet from the telescope. The comparisons have further to be corrected for selective extinction in this 600 feet of air, and a series of determinations of this has been carried out. A collimated beam of light is projected over the 600 feet, and then back by reflection from a plane mirror. The mirror is then brought up to within a few feet of the apparatus, and a photographic comparison gives the required quantity.

In addition to this absolute work, 12 comparisons between stars were obtained.

The results of the comparisons with the acetylene burner give a value of $13600° \pm 800°$ for the zero of the standard system, which corresponds approximately to an average Ao star.

Astrographic Equatorial.—During the year 126 fields were photographed through the glass for the determination of proper motions of stars in the Greenwich astrographic zone. 131 plates have been measured, and this completes the reobservation of the zone and the measurement of the plates.

During the month of January the instrument was employed for the photography of Eros, and 60 plates were obtained on 10 nights.

113 plates of 71 fields were taken for the purpose of determining the positions of the comparison stars used in the reduction of the Eros plates.

Photoheliograph.—Photographs of the Sun were obtained on 258 days at Greenwich and on 333 days at the Cape. On 5 days photographs were not taken at either observatory, but plates for these days are available from Kodaikanal. The mean daily spotted area, corrected for foreshortening, was approximately 260 millionths of the Sun's hemisphere, *i.e.* about half that of the previous year. The published mean areas for the years 1924–1930 are respectively 276, 830, 1262, 1058, 1390, 1242 and 516.

The spectrohelioscope lent by the Mount Wilson Observatory was used whenever possible for the detection of solar eruptions seen in $H\alpha$ light and for the measurement of radial velocities of bright and dark flocculi. Observations were made on 134 days. The results of observations of solar flocculi made with this instrument during the year 1930 were published in the *Monthly Notices* for 1931 March.

Sunspot numbers for the central part of the Sun's disc have been supplied to Zürich Observatory for the years 1918–1927 inclusive.

Clock and Time Service.—The free-pendulum clock, Shortt No. 3, has been used as standard sidereal clock throughout the year. No. 11 has been kept going as reserve standard, and regular comparisons are made with No. 3. The experimental pendulum with plain steel suspension spring, referred to in last year's report, was delivered by the Synchronome Co. in March, and is ready for substitution on one of the standard clocks.

The mean time free-pendulum clock, Shortt No. 16, has controlled all the mean time signal distribution throughout the year. The transmission of wireless time-signals through Rugby and the B.B.C. stations, in addition to the hourly telegraph signals, has been maintained regularly. A short series of preliminary signals, before the rhythmic signals from Rugby, was introduced at the beginning of June. These signals are sent automatically by apparatus controlled by the mean time clock.

The reception of wireless time-signals from Rugby, Nauen, Annapolis, and Bordeaux stations has been maintained and the results of the comparisons circulated in " Notices to Mariners."

Observations for clock correction were made on 65 nights with the small reversible transit B.

Observations of Eros.—During the 1930–1931 opposition 220 plates were taken on 45 nights (October 9 to January 31) with the astrographic equatorial and 115 plates on 21 nights with the 26-inch equatorial. These plates included 130 plates taken on 19 full nights (with as large a range of hour angle as was possible) by the astrographic, and 80 plates taken on 11 full nights by the 26-inch.

Eclipse of 1932 *August* 31.—Some work in preparation for the observation of this eclipse has been carried out. A stigmatic spectrograph for the observation of the chromosphere and corona in the extreme red has been constructed in the workshop. It incorporates a concave grating of 1 metre

focus ruled at the National Physical Laboratory. The preliminary tests have been very satisfactory.

Printing.—The volume, and separate parts, of *Greenwich Observations* for 1929, and also a volume of Photographic Magnitudes of Stars brighter than $14^{m}.0$ in Kapteyn's Selected Areas, taken with the 26-inch refractor over the period 1912 to 1920, have been distributed.

The proofs of *Greenwich Observations* for 1930 have been passed.

New Instruments.—A new transit circle is under construction by Messrs. Cooke, Troughton & Simms. It will be a reversible instrument generally similar in design to that at the Cape. The aperture will be 7 inches and the focal length 8 feet.

A generous offer to present a large telescope to the observatory was made by Mr. William Johnston Yapp on March 13. After careful consideration it was decided that a 36-inch reflector would be the most useful addition to the equipment. To meet the cost of this instrument, with spectroscopes and a new 34-foot dome, Mr. Yapp has given £15,000. This munificent and public-spirited gift has been gratefully accepted by The Lords Commissioners of the Admiralty.

Good progress is being made in the construction of the instrument by Messrs. Grubb, Parsons & Co.

Royal Observatory, Edinburgh
(*Director, Prof. R. A. Sampson, F.R.S., Astronomer Royal for Scotland*)

The 36-inch reflector was completed by the delivery of the spectrograph by Messrs. A. Hilger, Ltd., towards the end of March. Owing to some error it was then found that the retaining ring that had been prepared for it did not fit. This was put right without difficulty but entailed delay. A further fault was then found in the junctions of the heating wires which run through the felt lining of the outer cover of the instrument to regulate its temperature. Two of these were found defective, and were replaced. The temperature control could now be tested, and it was found that it would work only when the leads connecting it with the Cambridge Instrument Company's regulator, which is affixed to the wall, were completely independent and no other call was thrown upon the same accumulators. This was done at the cost of some slight complication, and the control is now satisfactory and effective to a fraction of a degree. These items are mentioned, not as indicating neglect or inefficiency within the observatory or outside, but rather because anyone experienced in setting a complicated instrument going will look for them. Attention is now being given to the quality of the star image produced by the Cassegrain combination, which is of 54 feet focal length. Visually it is much inferior to what might be expected, and photographically less so, but it is still capable of improvement. Both mirrors had been passed as excellent under the Hartmann test. At the present moment the Cassegrain mirror is dismounted to examine whether any improvement can be effected.

An opportunity occurred for acquiring a Bamberg reversing transit

instrument, of excellent construction though without an impersonal micrometer. Though it is anticipated that the time of the staff will be fully occupied otherwise in the near future, the instrument was acquired and cleaned, with the intention of supplying later an impersonal micrometer and arranging a location for observing.

Time work has been continued with no variation of plan beyond improvement of the chronographic system in certain details. Since precise temperature control of the cells was effected, the clock Leroy No. 1230 has become one of the most reliable of the four clocks. The clock Riefler No. 258 was cured of dropping seconds by a return to the original pendulum suspension, which had been changed. The clock Shortt No. 4 has been running with the original invar pendulum rod. It has shown a slow progressive leak in the case, which has not been located, accompanied by a gradual diminution of arc, while the rate was approximately steady. This would be accounted for if the diminution of arc was accompanied by nearly the gain of rate indicated by the theoretical circular error. This is of some importance, as a circular error has not hitherto been detected. Shortt No. 0 has behaved in a very regular fashion.

All the normal services of the observatory—time determination, reception of wireless time-signals from Greenwich, Paris, Hamburg, and Washington, the solar spectrograph, and routine work—has been continued as before.

Shelving has been provided for the geodetical and geophysical books, and these have now been catalogued.

Public visits to see the observatory and the instruments have been arranged, parties of considerable numbers having come on eight occasions on Saturday afternoons. The Director is indebted to the Edinburgh Astronomical Association for assistance in issuing tickets and providing stewards on each occasion.

Royal Observatory, Cape of Good Hope
(*Director, Dr. H. Spencer Jones, F.R.S., H.M. Astronomer*)

Reversible Transit-Circle.—Observations of 7411 meridian transits have been secured during the year, the Sun having been observed on 207 days, Venus on 135 days, and Mercury on 84 days. The total includes also observations of Vesta on 20 nights, of Eros on 39 nights, and 576 observations of stars for the supplementary list of Eros reference stars rendered necessary by the deviation of the planet from the path originally computed.

The current reductions are well advanced, results up to 1930 April 23 having been entered into the ledgers. The programme of observation of the present catalogue, comprising stars brighter than $7^{m}\cdot5$ south of decl. -30° and zodiacal stars, is nearing completion. The working list for a catalogue comprising stars brighter than $7^{m}\cdot5$ between decl. -30° and the equator, and some zodiacal stars, is in course of preparation.

A second series of observations of bright stars (with and without a wire-gauze screen reducing $4\frac{1}{2}^{m}$) for differential magnitude equation in right ascension and declination has confirmed the small values found from the

first series for the mean of all observers. A further series of observations is in progress to test whether there is a systematic difference in the magnitude equation determined from observations (*a*) with screen first, (*b*) with screen last.

8-*inch Transit-Circle.*—Observations of 4213 meridian transits have been obtained for the determination of the positions of reference stars required for the reduction of plates taken with the wide-angle triplet lens. Mean places have been derived from observations up to 1931 April 30.

Zone Observations.—The photography of the zone $-30°$ to $-35°$ decl. was commenced in June. Three exposures, each of 20 minutes, are being secured on each plate, and the overlaps in right ascension are such that each star appears on at least two plates. The number of plates obtained up to the end of the year is 58. The investigation of the screw errors of the long screw measuring machine shows that the periodic errors are quite negligible and the progressive errors are satisfactorily small.

Victoria Telescope.—The instrument was in use on 229 nights during the year, 1649 plates for stellar parallax and 86 plates for proper motion in declination of parallax stars having been obtained. 1648 plates have been measured during the year. A third list of parallaxes was published in the *Monthly Notices* during the year, bringing the total number of parallaxes published to 315.

Between January and May, 475 plates of Eros were obtained, 171 being at small hour angles and 304 at large hour angles. There are normally six images of the star field on each plate.

An electric motor has been installed to replace the hydraulic gear for turning the dome.

Astrographic Telescope.—678 plates of Eros were obtained during the first four months of the year, 210 being at small hour angles and 468 at large hour angles. In addition, 77 plates were taken along the corrected path of Eros for the determination of the positions of secondary comparison stars needed for the reduction of plates taken with long-focus instruments.

133 grating photographs covering the greater portion of the path of Eros have been obtained, and 6 grating plates of Eros, in order to control the final choice of comparison stars in relation to differential atmospheric refraction.

The measurement of the plates for proper motions in the Cape astrographic zones has been completed, 178 areas having been measured in both direct and reversed positions. The reductions are proceeding steadily, proper motions having been found for the whole of the zone $-41°$ to $-47°$ with the exception of 79 areas.

Opposition of Eros.—The observations of the primary reference stars of the supplementary list, together with a selection of the original stars to secure homogeneity, have been reduced and the results forwarded to Professor Kopff. The positions of Eros derived from the reversible transit-circle observations have been communicated to Professor Witt. A selection of the plates obtained in April with the astrographic telescope, and all the plates secured in May with the Victoria telescope, have been measured and

reduced. These results also have been forwarded to Professor Witt for use in the computation of the definitive ephemeris of Eros.

The measurement and reduction of the grating plates are in hand, and the selection of suitable comparison stars for the measurement of plates of the Victoria telescope series is proceeding.

Heliometer.—The following observations of superior planets near opposition have been obtained :—

Opposition of Jupiter	...	88 obs.	in	distance	on 7 nights.
,, ,, Mars	...	68	,,	,, ,,	,, 5 ,,
,, ,, ,, ...	...	12	,,	,, position angle	,, 2 ,,
,, ,, Neptune	...	74	,,	,, distance	,, 8 ,,
,, ,, ,,	...	4	,,	,, position angle	,, 1 ,,
,, ,, Saturn	...	68	,,	,, distance	,, 8 ,,
,, ,, ,, ...	...	8	,,	,, position angle	,, 1 ,,
,, ,, Uranus	...	64	,,	,, distance	,, 8 ,,
,, ,, ,, ...	...	22	,,	,, position angle	,, 5 ,,

Occultations.—22 observations were made of disappearance at the dark limb, 1 of disappearance at the bright limb, 7 of reappearance at the dark limb, and 3 of reappearance at the bright limb. The observations of the years 1923 to 1931 have been reduced.

Photoheliograph.—694 photographs of the Sun, including 28 for zero, have been obtained on 333 days to supplement the Greenwich series. In addition, visual observations for zero have been made weekly. Original negatives to 1931 November 19 and duplicate negatives to 1931 November 25 have been sent to Greenwich.

Time-Service and Wireless Signals.—Wireless signals of the international (ONOGO) type, controlled from the observatory, are emitted from the Slangkop wireless station daily, at 21^h U.T. on a wave-length of 625 metres, and at 7^h and 19^h U.T. on a wave-length of 36 metres.

Observations of scientific rhythmic signals have been made as follows :—

Rugby ...	...	...	10^h U.T. 251
Bordeaux	...	...	8^h U.T. 262

Night Sky Observations.—Observations to determine the brightness of the night sky, with the instrument supplied by Lord Rayleigh, were continued when conditions permitted until September 1, the date when H.M. Astronomer sailed for Europe. The observations were then temporarily discontinued as, in view of small systematic differences found to occur between different observers, it seemed preferable that the observations at any one place should be made by one observer only.

Seismograph.—The Milne-Shaw seismograph has been maintained in operation throughout the year. Details of the records up to the end of 1930 have been forwarded for incorporation in the International Seismological Summary, and information relating to microseisms and large earthquakes has been supplied to several investigators. The records are now discontinued, and the seismograph is to be erected at the University of

Cape Town, to examine whether or not the intense microseisms are purely local.

Annals.—Vol. x., part 9, containing a discussion of observations of Nova Pictoris, and vol. xiii., part 3, containing a rediscussion of the material contained in Newcomb's *Occultation Memoir*, are in the hands of the printer.

Miscellaneous.—A new block has been built, providing additional office, library and store-room accommodation.

H.M. Astronomer was granted six months leave from September 1, and has visited a number of the American and Canadian observatories, by invitation of the Carnegie Corporation.

Armagh Observatory
(*Director, Rev. W. F. A. Ellison*)

The very unfavourable weather of the past eighteen months reduced astronomical observations to a minimum. During the opposition of Mars in the early weeks of 1931 only four drawings of the planet were secured, and this may be taken as typical of the amount of work obtainable all through that winter and spring. While sunshine was deficient during daylight hours, the deficiency of clear skies at night was even more marked. Of the two total eclipses of the Moon, in April and September, only a small part of the partial phase was observable in the first and nothing at all in the second —an unprecedented run of ill-luck.

The shutters of the transit room were out of order for nearly two years, no funds being available for the work which should really be done to bring them up to modern requirements. In 1931 July, taking advantage of a spell of moderately fine weather, the Director was enabled to repair them so far as to fit them for work again. They still, however, leave much to be desired. Transits have since been taken at intervals, and the rate of the old Earnshaw clock checked. After going for two years without a check on its rate, it was found to be 37 seconds slow when transits were resumed.

The meteorological side of the observatory's work is directed by the Air Ministry, and has continued without interruption since 1833, and in some of its branches since 1793. In 1931 the coldest day was January 6, with maximum temperature 27·8°, minimum 21·5°; and the warmest, August 4, with maximum 74·2°, minimum 50·0°. The wettest month was July, with a rainfall of 5·73 inches, closely followed by June with 5·03. The driest month was March, with 1·47 inch. The wettest day was July 6, with 1·32 inch.

Cambridge Observatory
(*Director, Sir A. S. Eddington, F.R.S.*)

The object-glass of the Sheepshanks telescope was away from April to November for refiguring and repolishing. This was necessary owing to the deterioration of the surface of the flint lens mentioned in the last report.

As the result of refiguring, the focal length is slightly increased, but not so much as to cause difficulty in the focussing range of the instrument. The telescope has therefore been out of use for the greater part of the year, and in the earlier months observation was greatly hindered by the bad performance of the deteriorated lens.

Observations of Eros were made on as many nights as possible up to February 6 ; 30 plates were taken during the opposition, the total number of exposures being about 300. Examination of the photographs shows, however, that the handicap of the failing object-glass was too great, and it is unlikely that anything of much value can be obtained from these plates.

Measurement of proper motions has been continued. Plates taken during the last thirty years have been surveyed for double stars. A list of measures of 177 double stars was published by Dr. Smart in *Monthly Notices* for November. The number measured and reduced now amounts to 263.

Mr. R. D. H. Jones, B.A., has completed a research on star-streaming and space-distribution of the stars of Boss's Catalogue. Mr. Alan Fletcher, M.A., has discussed the orbit of 61 Cygni. Both these investigations have been communicated to the Society. Mr. Fletcher has also been using the Thorrowgood telescope for the measurement of double stars. Mr. M. H. H. Walters, B.A., is now working on a theoretical problem of stellar encounters. Mr. R. H. Stoy, B.A., has been engaged on the theory of planetary nebulæ.

A new dome has been ordered for the Northumberland telescope and will be erected in the coming long vacation. This instrument (which is now 3 years short of its centenary) is in constant use for showing celestial objects to large numbers of students and for instructional purposes.

Solar Physics Observatory, Cambridge University
(Assistant Director, R. O. Redman, M.A., Ph.D.)

Staff.—The observatory has been unfortunate in being without the services of its Director, Professor Stratton, for a large part of the year. He is at present on sick leave, and is spending the winter in Jamaica. Since his departure in October, Professor C. T. R. Wilson has been kind enough to act as Deputy Director. Dr. R. O. Redman commenced duties as Assistant Director at the beginning of April. Mr. T. Arthur has been appointed as additional assistant in the workshop and with the photographic work.

Professor Wilson and Mr. P. I. Dee have continued their investigations at the observatory on cloud tracks in expansion chambers. Mr. E. Gwyn Williams has concluded his study of the contours of hydrogen lines in stellar spectra, and an account of the work is ready for the press. In August he proceeded with a Commonwealth Fund Fellowship to the Mt. Wilson Observatory, Pasadena. Dr. R. v. d. R. Woolley has returned to Cambridge from that institution, and has commenced observational work on the contours of lines in solar spectra. Mr. J. Evershed has been very kindly co-operating by the provision of special spectrograms.

Mr. G. B. B. M'I. Sutherland has been investigating with the 21-foot Rowland grating the absorption spectra in the region 7000–9600 A. of a number of gases and liquids. He is continuing the work at the University of Michigan, where he holds a Commonwealth Fund Fellowship.

Mr. H. C. Webster of the Cavendish Laboratory, who has been working at the observatory to avoid radioactive contamination, has concluded experiments for the study of nuclear γ-radiation artificially produced by α-particle bombardment. Mr. A. W. Mailvaganam has continued work on the resonance radiation from sodium vapour.

Solar Work.—This has remained in charge of Mr. Butler. Owing to unusually poor weather during the summer and to time spent on experiments with an interferometer in the *Hα* train, the number of spectroheliograms obtained this year has again been below the average. Photographs of the Sun's disc in K_{232} light were obtained on 39 days, and photographs of prominences at the Sun's limb on 30 days.

For the year 1930 October 1 to 1931 September 30, the Director of the Kodaikanal Observatory has sent 333 spectroheliograms showing the Sun's disc in K_{232} light. Bromide prints of 637 photoheliograms from negatives taken at Greenwich, the Cape, and Kodaikanal observatories have been received from the Astronomer Royal for the period 1929 January 1 to 1930 September 30.

A spectrohelioscope has been erected and is now practically complete. By the kindness of Dr. Hale of the Mt. Wilson Observatory, a double-slit end of one of his standard instruments has been received, fitted with the rotating rectangular prisms devised by Dr. Anderson. The other necessary fittings have been made in the observatory workshop. Two 3-inch concave mirrors for this instrument have been purchased from Messrs. Grubb, Parsons & Co.

Dr. Wormell has continued his study of thermocouple observations of radiation from limited regions of the Sun's disc.

Plans are being made to adapt the McClean solar spectrograph, at present a grating instrument, so that it may also be used with prisms.

Stellar Work.—A new spectrograph has been designed and is being built in the workshops for use with the 3-foot Common reflector. For this, two prisms, already in the possession of the observatory, have been refigured by Messrs. Hilger, Ltd., to give the best optical quality obtainable. Overhaul of the telescope itself has been continued, and it is now in regular use. Pending completion of the spectrograph, the possibilities of a programme of photographic photometry (direct photography) of nebulæ are being explored.

On the Newall 25-inch refractor a photometric programme has been continued with the 2-prism spectrograph. A number of plates have been taken and some improvements made in technique, but this work particularly has been hindered by the Director's absence.

Laboratory Work.—Mr. Moss and Dr. Dobbie have continued work on the spectrum lines found near the poles of the iron arc run with a very low current. An extensive series of photographs has been taken with the Rowland grating and also with prism instruments, covering all regions

between λλ 2500 and 7500. These photographs are now in process of measurement and study.

Meteorological Physics.—Dr. Wormell has continued observations of the electric fields produced at the ground by thunderstorms. A start has been made with an attempt, by means of balloons, to detect penetrating radiation within thunderclouds.

Instruments and Buildings.—The mirror of the 20-inch Common reflector has been refigured and returned from Messrs. Grubb, Parsons & Co. For this instrument a 16-foot dome has been erected west of the spectroheliograph house and south of the main building. The old meteorological hut, which has seen many years of service, has been replaced by a new and larger one. Concrete floors and electric-current supply have been provided in both these buildings.

A new screw motion has been fitted by the Cambridge Instrument Co. to the photo-electric microphotometer, and has greatly facilitated setting on given regions of the plate. The compensating gas-filled photo-electric cell has been replaced by one of the cæsium vacuum type, similar to the recording cell, and by this means a troublesome hysteresis effect has been overcome. A new microscope objective with improved performance in the near infra-red has been fitted in place of the lower one originally on the instrument.

Two 12-inch F3 Aldis lenses have been purchased for a spectrograph for the 20-inch Common reflector.

Solar Eclipse of 1932 *August* 31.—It is hoped to send a party to observe this eclipse. The camp will probably be situated near Magog, Quebec, and active co-operation is being offered by Professor A. S. Eve of McGill University. Instrumental preparations have been commenced.

Dunsink Observatory
(*Acting Director, Mr. Charles Martin, M.A.*)

The time service to Dublin has been continued as in previous years. The meridian circle has been used only for time determination.

The observatory has been used mainly for teaching purposes, students being welcomed for instrumental instruction and observational work.

Durham University Observatory
(*Observer, Mr. Frank Sargent*)

The observatory continues under the direction of the small committee appointed by the Board of Curators.

During the year daily meteorological observations have been made and forwarded to the Meteorological Office. The work on variable stars has been continued and 604 observations recorded. The observer also carried out a watch for Lyrid meteors in April and for Orionid meteors in November. Observations have also been made of the markings in the belts of the planet Jupiter.

Seismological records have been taken daily on the Milne-Shaw seismograph, and analyses are being forwarded to the International Bureau.

The Observer published a short paper in *M.N.*, **91**, 602, on the variability of B.D. $+72^{\circ}\cdot733$.

Imperial College Observatory, South Kensington
(*Director, Assistant-Professor H. Dingle*)

During the year the dome of the 5-inch refractor has been repaired and the telescope and accessories are now undergoing renovation. The 6-inch Simms No. 2 telescope, on loan from the Royal Observatory, Greenwich, has also been thoroughly overhauled. The usual courses of instruction to students have been carried on in unusually bad weather. Observations of the Moon have been made by Mr. Tidmarsh, of the Imperial College, in connection with certain geological investigations which he is pursuing. Both eclipses of the Moon, on April 2 and September 26, were quite invisible owing to clouds, and arrangements which had been made for photographing the spectrum of the Moon during totality were thus frustrated. Preparations for the expedition to Montreal to observe the total eclipse of the Sun of 1932 August 31 have begun, and a spectrograph of high dispersion is being designed. The programme includes the photography of the bright-line spectrum at the cusp of the partially eclipsed Sun, and of the Fraunhofer spectrum at the limb immediately before and after totality, the object being to secure accurate wave-lengths over a small region of the spectrum.

Laboratory work has been continued in various branches of spectroscopy, and several papers have been published during the year. The Fabry-Pérot interferometer referred to in last year's report has been received, and also a considerable quantity of valuable spectroscopic apparatus under the bequest of the late Colonel Gifford.

Liverpool Observatory and Tidal Institute
(*Director, Professor J. Proudman ; Associate Director, Dr. A. T. Doodson*)

Tidal predictions of high and low water have been made for 67 places ; of hourly heights of water for 2 places ; and of times of slack water for 3 places. Five years' records of tidal observations from 3 places have been analysed. Much research has been carried out on tidal dynamics, both for actual and for ideal basins, and in this work Dr. S. F. Grace, of the University of Liverpool, has taken a considerable part.

The regular meteorological and seismological services of observation and transmission of information, and the firing of the time-gun, have been continued unbroken.

In July the Liverpool Observatory and Tidal Institute was honoured by a visit from a large party of members of the Conference of Empire Survey Officers. In May and June Dr. J. E. Fjeldstad, of the Geophysical Institute at Bergen, spent several weeks at the observatory.

University of London Observatory, Mill Hill, and University College Observatory

(*Director, Professor L. N. G. Filon, F.R.S.; C. C. L. Gregory, Wilson Observer*)

The Wilson Reflector.—Very little work has been done with this instrument during the year on account of almost continuous bad weather. The instrument was used on 37 nights, when only 20 plates were obtained, mainly of nebulæ, and a few Hartmann plates to test both the Newtonian and Cassegrain foci. The screws which operate the double cross slides of the breech-piece have been fitted with new and much larger heads, divided to read hundredths of a turn. Also, scales have been fitted to the cross slides to read the whole number of turns. A new relay has been introduced in the synchronising device of the driving clock, as the second signals were found to take a current which was too large for the synchronome switch. The arrangement is now satisfactory. Improvements have also been made in the method used for eliminating plate tilt.

Rowland Grating Spectrograph and 8-inch Cœlostat Telescope.—A number of comparison plates were taken of Sun, iron arc and furnace spectra. The cœlostat was also used in conjunction with the Littrow spectrograph for stellar spectrograms, a small telescope being permanently mounted for viewing the image of the star on the slit-plate, which is made of stainless steel and optically finished. The arrangement, however, was found not to have a sufficient light grasp for satisfactory plates to be obtained with reasonable exposures. The present mirrors of the cœlostat are not large enough to fill the 8-inch object-glass. The loan of a larger mirror has been granted by the Council of the B.A.A., and fresh attempts will be made when this is mounted. In consequence, the Littrow spectrograph was dismantled early in the year, and was used for accommodating Mr. Herbert's new amplifier and photo-cells for stellar photometry. The amplifier consists of a bridge arrangement, in connection with a Paschen galvanometer kindly lent to the observatory by Professor A. V. Hill, and a cæsium cell kindly lent by the department of Physical Chemistry at University College. This was afterwards used in conjunction with the Fry 8-inch telescope on bright stars. The arrangement seemed promising, and accordingly a larger instrument on this pattern has been designed, and is nearly completed, for use with the Wilson Reflector.

Fry 8-inch Refractor.—Early in the year this instrument was provided with a projecting apparatus for measuring the positions of sunspots. Forty-two observations of sunspots were made during the year. In addition, the telescope was used on 107 nights, but the greater number of these were too bad for reliable observations. Observations of 19 occultations were attempted, but owing to cloud only 4 were satisfactory. Observations were made on a number of double stars, both with the bifilar micrometer and with a slightly modified form of the Michelson slit interferometer. Mr. Frank Robbins has taken an active part in the use of the Fry telescope and

in obtaining the errors of the clocks from the broadcast time-signals. The results of occultations observed during the year 1930 were published in the *Monthly Notices* for 1931 June.

Measurement of Plates.—Miss White, a research student, commenced measuring plates taken with the Wilson telescope since its re-erection at Mill Hill, and also plates of the same regions (for the most part centred on the larger nebulæ) taken with the same instrument about forty years ago, when it was at Darramona, in Ireland. Preliminary drift curves indicate that the measures are satisfactory.

Furnace and Sun plates have now been measured by Miss Williamson, and it is hoped that these results will shortly be ready for publication.

Visitors.—The same arrangements have been made regarding visitors as those shown in last year's report. The total number of visitors during the year was 211.

University College Observatory.—The work, which is mainly instructional, has been carried on as in previous years. The 4-inch Chadwick equatorial, by Cooke, was dismantled at the end of the year and reconditioned in the College workshop.

Radcliffe Observatory, Oxford
(*Director, Dr. H. Knox-Shaw, Radcliffe Observer*)

The observational programme on proper motions in the Selected Areas is drawing to a close and should with reasonably good fortune as regards weather be completed by the spring of 1933. During the year 47 proper-motion plates were taken, and of these 28 have been passed for measurement; there are 29 plates still to be obtained. Measurement and reduction are following closely behind observation, and final figures have now been derived for the proper motions of about 23,000 stars in 79 areas. A list of the stars, in the first 73 areas to be completed, with proper motions greater than $0''{\cdot}1$ per annum has been published in *M.N.*, **91**, 933.

On eleven nights in January and February 59 plates were exposed on Eros when near the meridian, for use in the determination of the solar parallax by the north–south method. Of these plates 50 have been sent to Greenwich for measurement along with those obtained there.

The reduction of Hornsby's meridian observations has been written up and is now in the press.

It is likely to be some time yet before a decision is obtained as to the future of the observatory.

University Observatory, Oxford
(*Mr. F. A. Bellamy, Acting-Director*)

The past year has been a most active one in many ways, which can only be briefly recorded here.

The *Astrographic Catalogue*, zone centres $+32°$ to $+35°$, taken over from the Potsdam Observatory, has proceeded with all possible speed. Turner's standard co-ordinates for about 10,000 reference stars have been

computed and other work done; but the want of funds prevents the measuring proceeding with the three available instruments. If more measuring could be done and a reasonable number of sufficiently fine nights occur, half the zone $+32°$ (80 plates) might be ready for printing by the end of June. Every effort is being made to push on the zones to completion.

The manuscript proposed to form vol. xi of the *Vatican Observatory Astrographic Catalogue* has been sent to Fr. Stein and its printing is proceeding; it is a summary of the residuals, Vatican plates *minus* Helsingfors Catalogue stars, together with numerous notes. The proof-sheets will be read at Oxford with the original work, which has occupied us during 20 years. In taking up these additional zones at Oxford, the measurement of the plates in (Santiago) zone $-22°$ ceased at R.A. 18^h.

A considerable number of Professor Turner's books were purchased for the observatory and form a valuable addition to the library; included is a copy of *Bevis's Star Maps*. The whole library has been rearranged and extended into the new wing.

Professor E. W. Brown and Miss M. A. Blagg came in July and discussed the lunar map (Wesley's drawings) and the material left here by the late Mr. Saunder; all the map drawings have been sent to Miss Blagg.

The work of the preparation and printing of the *International Seismological Summary* has been continued without any change, about 425 pages of the 1927–28 results having been printed during the year. Numerous requests for records and information have been attended to by Miss E. F. Bellamy.

At the request of the Joint Permanent Eclipse Committee the complete set of eclipse instruments, in six cases, has been lent to the Solar Physics Observatory, Cambridge, and the 12-inch plane mirror to Professor Dingle, for use in the solar eclipse of 1932 August.

On December 1 last, Professor H. H. Plaskett, Professor of Astrophysics in Harvard University, was appointed Savilian Professor of Astronomy; he takes up his duties here next June.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth
(*Director, William J. S. Lockyer, M.A., Ph.D., Major (late R.A.F.)*)

The Kensington 9-inch prismatic camera has been in regular use throughout the year for the purpose of photographing the spectra of the brighter bright-line stars of spectral type Be. The Zeiss triplet lens attached to this instrument has also been used, chiefly for the photography of star regions during part of the time of the exposure of the spectra. Occasional photographs have been taken with the two fixed meteor cameras, which are erected near the Kensington dome. The McClean 12-inch prismatic camera has been used frequently but irregularly, chiefly for the routine photography of stellar spectra, with special attention to the fainter B-type stars.

There were 130 fine nights during the year, which is only slightly below the average annual number (132), and is an improvement on the previous year's record (118). Successful observations were made on 125 of these nights. The numbers of negatives secured with the Kensington instruments

were as follows: 228 with the 9-inch prismatic camera, 34 with the Zeiss triplet for star regions, 7 with the large doublet camera, and 12 with the Zeiss triplet meteor camera. Sixty-six negatives were secured with the 12-inch McClean telescope.

Work has been continued on B-type stars which show bright hydrogen lines in their spectra, and a star in which such lines have been recorded for the first time is noted in *M.N.*, **91**, 259. Work has also been continued on the spectra of B-type stars in general, from the point of view of classification, the study of peculiarities, and the determination of spectroscopic parallaxes. A paper on the relation between the solar corona and prominences was published in *M.N.*, **91**, 79, in which previous work on this subject is brought up to date and confirmed by recent observations.

The new mounting constructed by Messrs Cooke, Troughton & Simms, Ltd., to carry four Zeiss triplet lenses of various apertures and a finder, together with an electric-control pendulum for the driving clock, and the dome and annexe, were all presented to the observatory by Dr. Robert L. Mond, and were erected during the current year. Photographs were taken for the adjustments of the mounting, the clock rate, and the foci of the cameras during November and December. The instrument has performed very satisfactorily, and all is now in fairly good adjustment.

The observatory is open to the public on Wednesday afternoons, and was also opened to a special party of visitors on one evening during the summer. The total number of visitors who attended during the year was 306, including students from the University College of the South-West (Exeter) and other special parties.

The fifteenth annual general meeting of the Norman Lockyer Observatory Corporation was held in London on June 11.

Stonyhurst College Observatory
(*Director, Rev. E. D. O'Connor, S.J., M.A.*)

The staff of the observatory remains unchanged.

In the course of the year the dome was repainted, the roofs of the adjoining rooms were refelted, and new rollers were fitted to the top of the shutter.

The meteorological, magnetic and seismological records have been maintained, and the results forwarded to the official centres. Absolute measures of the horizontal magnetic force and of the inclination have been made once each month, and the declination has been observed once each week. The total number of earthquakes recorded during the year was 87, as against 97 in the previous year and 129 in 1929. A small tremor, which was felt in the Manchester area on May 3, and the North Sea earthquake on June 7, both of which aroused a good deal of local interest, were well recorded, and Father Rowland made a detailed study of the latter. The year was notable for the two largest earthquakes so far recorded at this observatory since the installation of the Milne-Shaw seismograph in 1923 September. These were respectively on May 20, with epicentre in the Atlantic Ocean, about 300 miles west of Portugal, and on August 10, in the Sin Kiang province of

China. In both these cases the range of movement on the record was over 7 inches.

The work on synoptic meteorology has been continued, a daily weather forecast for the district issued in the *Lancashire Daily Post*, and a daily chart posted up in one of the main corridors at the college.

Observations of the solar surface were made on 257 days, and include 268 drawings. Of these, 245 are complete, showing all spots and faculæ, whilst of the remaining 23, 7 are complete for spots. Professor Brunner of Zürich and Professor Favaro of Catania have again placed their drawings at our disposal, and a drawing for April 4 has been supplied by Professor da Costa Lobo of Coimbra, with the result that we have at least one drawing for each day of the year except January 8, 21, 23 and February 20. Using all the drawings, the mean daily spotted area (in units 1/5000 of the disc) works out at 1·26 as compared with 2·25 in 1930 and 6·19 in 1929. There were 46 spotless days. Corresponding to the decrease of solar activity, there is a decline in magnetic activity, as shown in the diminished mean ranges both for quiet days and for all days, and in the marked falling off in range of the principal disturbances—none of which attained the character of " very great " in our classification.

Sunspot statistics have been sent regularly to Professor Brunner for the preparation of the sunspot numbers. Charts of the solar surface for each rotation, showing all spots and faculæ, have been drawn, together with reduced copies of the horizontal force magnetograms.

Prominence observations were made on 32 days between June 17 and October 31, a small grating spectroscope being substituted for the cumbersome 12-prism Browning spectroscope on the 15-inch equatorial. There were no opportunities of observing in November and December. The heliostat and Hilger solar spectrograph have been again mounted and adjusted, and work is in progress with a view to converting the whole into a spectrohelioscope.

The weather during the year was again very unfavourable for night work. Eight lunar occultations were observed, and the results sent to Dr. Comrie. All the others listed as visible at Greenwich were unobservable owing to bad weather. A few plates were exposed on some of the Herschel nebulous fields, using a Wratten No. 16 filter, but no results were obtained. Further visual observations of the fields were carried out.

Arrangements were made to keep the sky under observation for the November Leonids, but the only time when it was sufficiently clear to observe was on November 17, from 4.0 a.m. to 6.0. a.m. During that time 13 Leonids were counted, and the results of the observation were communicated to *Nature*.

A number of scientific societies and individuals visited the observatory during the year ; and parties of boys from the school, as usual, were shown the various instruments, their use being explained to them. Opportunity was also afforded to view interesting objects through the 15-inch equatorial.

The Director and Father Rowland delivered a number of lectures to various societies.

Dominion Observatory, Ottawa, Canada
(Director, Mr. R. Meldrum Stewart)

Meridian Work and Time Service.—In the regular programme work of the meridian circle there were obtained, on 210 observing days, 2880 observations for right ascension and declination of stars and 200 of the Sun, Moon and planets. On 43 nights observations for clock correction were made also with a 3-inch transit. The time-service was maintained as in previous years, with no material changes. Wireless time-signals were received regularly from Rugby, Annapolis, Bordeaux and Nauen, the reception being made by coincidence, by extinction and, when convenient, by registration. Time-signals were broadcast at 3 p.m. daily, except Sundays, through CNRO on concert wave-length, and daily through the observatory station on wave-lengths of 90, 40·8 and 20·4 metres.

Solar Physics.—Over 100 nine-strip solar and iodine absorption spectrograms at λ 5600 were obtained in connection with the programme for the determination of solar rotation, and the measurements and computations of solar spectra were continued. About the same number of direct photographs of the 9-inch solar image were taken. Investigations of solar and tidal periods, and their effect on climate and on various forms of life, were carried on, with special reference to Canada. Certain results obtained were contributed in the form of papers to the 1931 Canadian Biological Congress on cycles. Oceanic and inland reactions of opposite phase have been found, and half-periods noted in geographic regions subject to both reactions.

The 15-inch Equatorial.—The telescope was employed mainly in the further study of triple or peculiar spectroscopic binary systems, about 120 spectrograms being obtained. The stars chiefly studied were χ Draconis, ϵ Aurigæ, η Virginis, α Canum Venaticorum and β Lyræ. A new photo-electric photometer was designed, and was constructed in the observatory workshop. Considerable work of an experimental nature has been done with this instrument, and several improvements made. A Lindemann electrometer is used instead of the former string electrometer, and more accurate results are anticipated. As in former years, the telescope was made available to visitors every clear Saturday evening. On dull evenings lantern slides were shown.

Photographic Photometry.—The international programme on Cepheid variables has been continued in so far as it includes the preparation of lists of comparison stars. Some fifty plates were obtained with double exposures for the determination of the magnitudes of the comparison stars, and the plates of several of the fields have been prepared for measuring. Owing to the protracted illness and subsequent death of the astronomer, Mr. R. Callander, only a small amount of observing was done for the light-curves of the Cepheids.

Seismology.—During the year 312 earthquakes were registered, of which 24 were reported to the Press and 20 by telegraph to Science Service at Washington, D.C. The epicentres and dates of the three largest earthquakes

occurring in 1931 are as follows: Mexico, January 15; Turkestan, August 10; New Hebrides, October 3. The seismographs at Ottawa, Saskatoon, Halifax, Shawinigan Falls and Seven Falls have been in practically continuous operation throughout the year.

Terrestrial Magnetism.—Magnetic work during the year was confined to the occupation of repeat stations for secular change of the magnetic elements. Observations were made at thirty-five stations representing thirty-four localities. Twenty-three of these stations are distributed over the territory lying between longitudes 61° W. and 75° W., and south of latitude 49° N. The remaining stations are all in Western Canada, nine being along the water route to the Arctic Ocean, between latitudes 58° N. and 68° N.

Gravity.—In continuation of the work of 1930, magnetometric surveys were made in the vicinity of Thetford, Quebec, for the purpose of further investigating the relation between the anomalies and the occurrence of the minerals asbestos and chromite. In co-operation with the Ontario Research Foundation and the Ontario Department of Mines, geophysical investigations of a preliminary character were made in Northern Ontario. These consisted of a gravitational survey, with the torsion balance, of the Onakawana lignite deposit, and a magnetometric survey of the siderite deposit at the Grand Rapids on the Mattagami River. A report on the torsion balance investigations of 1929 was published as a part of Memoir 165 of the Geological Survey of Canada, and two reports on the geophysical work of 1930 have been prepared for publication. Progress has been made with the various reductions in connection with the 129 pendulum stations now established in Canada, in preparation for the report on the work which it is proposed to publish in the near future.

Publications.—Eight numbers of the regular series of Dominion Observatory Publications were issued, as follows: Vol. vi, Part 1, Section 7, *A Device and Tables for Computing the Components of the Orbital Velocity of the Earth to Points on the Sun*; vol. vii, No. 6, *Empirical Investigation of Surface-Waves Generated by Distant Earthquakes*; vol. x, Nos. 7, 8, 9, 10 and 11, *Bibliography of Seismology*; vol. xi, No. 2, *A Determination of the Relative Values of Gravity at Potsdam, Greenwich, Ottawa, and Washington.*

Dominion Astrophysical Observatory, Victoria, B.C.
(*Director, Dr. J. S. Plaskett, F.R.S.*)

Dr. R. O. Redman, who resigned from the observatory staff towards the end of 1930, left in February to accept the Assistant Directorship of the Solar Physics Observatory, Cambridge. The vacancy was filled by the appointment of Dr. Frank S. Hogg in August. Otherwise the staff remains unchanged. Professor H. H. Plaskett of Harvard, Mr. R. M. Petrie of Michigan, and Mr. A. McKellar of California spent some two months each in the summer at the observatory. Professor Plaskett was engaged mainly in photographing the spectrum of the solar disc at the secondary focus of the 72-inch in an attempt, apparently successful, to obtain the spectra of the granulations. Mr. Petrie made high-dispersion spectra of some Cepheids

for the investigation of line contours at different phases, while Mr. McKellar was mainly employed in the measurement and reduction of spectrograms.

The observing weather for the year, even though meteorological records show an increase of 5 per cent. in sunshine, has been slightly below the average. There were 1180 hours' observing on 196 nights as compared with the thirteen-year average of 1265 hours on 205 nights. The number of spectra obtained, 913, is considerably below the yearly average of 1471, but this is, of course, mainly due to the increasing faintness of the stars observed. The number of stellar spectra measured for radial velocity was 861, but photometric measurements of different kinds were made on a large number of spectra. The Saturday open nights have been continued as usual, the number of day and night visitors, however, showing a considerable decrease from 33,000 to about 25,000, nearly 25 per cent.

The Director, in collaboration with Dr. J. A. Pearce, has continued the discussion of the radial velocities of the O to B5 stars, which have been under investigation at Victoria since 1923. The Victoria observations of the radial velocities of 523 of these stars have appeared in vol. 5, no. 1 of the *Observatory Publications*, while no. 2 of the same volume, which is to be devoted exclusively to this work, is a general catalogue of all known velocities of stars of types O to B5, containing 1611 determinations from 16,069 spectra of 1010 stars. Both of these numbers have been printed and will shortly be distributed. The manuscript of vol. 5, no. 3, on the interstellar diffuse matter, is practically completed. This number contains a catalogue of the interstellar velocities from 314 stars, along with the corresponding stellar velocities and estimates of the intensity of the interstellar K line. The joint discussion of this material has yielded results of considerable interest and importance, the principal ones being the demonstration of the participation of the diffuse matter in the rotation of the galaxy, of its uniform distribution throughout the portion of the stellar system inhabited by the O- and B-type stars, and of a direct linear relation between the intensity of the K lines and the distances of the stars. This latter relation, besides confirming the uniformity of distribution, provides the most reliable method known of obtaining individual distances of these very remote stars.

Mr. W. E. Harper has continued observation and measurement on the programme of the radial velocities of A-type stars which is now nearly completed. The final catalogue will contain velocities from upwards of 1100 A-type stars. During the year 367 spectra have been obtained and 575 measured. Accessory to this work has been a discussion of the systematic differences in A-type velocities between Victoria and other observatories, Victoria being slightly more negative. Suggested explanations were given in a paper read at the Royal Society (Canada), and the work is being continued. The large number of measures has also enabled considerable data on wave-lengths in A-type spectra to be discussed. In addition, the orbit of the spectroscopic binary H.D. 125335 has been determined, and periods and preliminary elements obtained for two other stars, H.R. 1528 and H.R. 6290.

Dr. J. A. Pearce has continued his observation of B-type stars fainter

than magnitude 7·5 and north of the equator, 210 spectra being secured, as well as others of " c " stars and binaries. He has collaborated with the Director in vol. 5, no. 3 on the diffuse matter, and obtained, from the intensities of the interstellar lines, the absolute magnitudes of 297 stars. The single example of a star of type later than B5 containing interstellar lines, the spectroscopic binary H.D. 698, B9sek, was discovered and investigated by him, thus confirming Eddington's theory that the interstellar lines should appear in stars of types other than O to B5. This star is further interesting in being the most massive double-lined binary so far investigated, the minimum masses being 134 and 50 times the mass of the Sun, with a period of 55·9 days. A number of B3 and B5 binaries were also investigated for the coexistence of stellar and interstellar calcium, this being found in several spectra of stars which are sufficiently remote to show interstellar absorption and have sufficient velocity amplitude to separate the stellar calcium from the interstellar.

Dr. C. S. Beals has made extended spectrophotometric observations of the forms of emission bands in Wolf-Rayet stars and has also studied the emission bands in Nova Aquilæ and Nova Cygni. A theory of band contours has been developed which accounts satisfactorily for the flat-topped bands which occur in novæ and in some Wolf-Rayet stars. Spectrophotometric observations of interstellar lines have been continued, a considerable amount of material has been accumulated and some preliminary photometric measures made. In the laboratory a photo-electric microphotometer of the direct-reading type has been constructed and has proved highly convenient and efficient for the measurement of photographic densities in stellar spectra.

Dr. Frank S. Hogg has commenced a spectroscopic examination of the brighter nuclei of the planetary nebulæ with a spectrograph of rather small dispersion. A number of direct photographs of globular clusters have been taken for a study of the variable stars contained therein, both in the search for new variables and in the determination of light-curves. Researches on the distribution of stars in clusters are also in progress.

Mr. S. N. Hill has spent considerable time in the reduction of proper motions of B-type stars for statistical purposes, and has assisted in general computing work.

There have been printed during the year *Publications*, vol. 4, nos. 15, 19, 20, 21 and index, vol. 5, nos. 1, 2, and vol. 6, nos. 1, 2, 3 and 4. Vol. 6, no. 5, containing the final results of Redman's work on the galactic rotation of faint K-type stars, is in press, while vol. 5, no. 3 is nearly ready for publication. Several articles in astronomical periodicals have appeared during the year and the weekly seminars have been successfully continued.

Helwan Observatory, Ministry of Public Works, Egypt
(*Director, Mr. P. A. Curry*)

Time Service.—The time service was maintained as usual, the error of the standard clock, Shortt No. 1, being determined daily from the Bordeaux and Rugby rhythmic wireless signals. On March 1 the slave pendulum of

Shortt No. 1 stopped, and before it could be put right it caused the free pendulum to stop also. This necessitated the opening of the case of the free pendulum, which had run well without attention since it was first installed in 1924 November. The opportunity was taken to clean the contacts, overhaul the movement and adjust the rate. It was not until July that the Shortt clock was again taken over as standard, the Riefler clock being used in the meanwhile. Considerable difficulty was experienced in getting Shortt working satisfactorily again, mainly owing to a slow air leak into the case; but this was eventually overcome, and for the remainder of the year the clock ran very well.

The reversible transit was used occasionally throughout the year. The remounting of the level bubble is not yet entirely satisfactory, and this will have to be remedied before regular transit observations of the highest accuracy can be resumed.

Reynolds Reflector.—The telescope was used on 40 nights; 33 plates were exposed on various nebulæ, 4 on Eros, 3 in search of J VIII and 2 for focus.

General.—The usual meteorological, magnetic, seismological and solar radiation observations were made.

A new Schuster-Smith magnetometer, made by the Cambridge Instrument Company, was installed in the summer, and is giving very satisfactory results.

Nizamiah Observatory, Hyderabad
(*Director, Mr. T. P. Bhaskaran, M.A.*)

Astrograph.—The astrographic equatorial was in use on 81 nights and the number of plates obtained was 257; of these, 191 plates with multiple exposures were taken in connection with the observations of Eros during opposition for the determination of solar parallax; the remaining plates were exposed in the region of the old Potsdam zones ($+36°$ to $+39°$) for the purpose of the catalogue, and in that of the Hyderabad zones for comparison with the early plates of the series. 34 plates have been measured for the catalogue and 12 repetition plates for proper motion during the year. A start has also been made with the measurement of the Eros photographs, and 14 plates have been measured up to the end of the year.

The measurement and reduction of plates in zone $+39°$ have been completed and the MS. of the catalogue for this zone is well advanced. It is hoped that arrangements will be made for the printing of this volume early in 1932. Steady progress has also been made with the measurement of plates in zones $+38°$ and $+37°$. The publication of the measures in the Hyderabad zones $-17°$ to $-23°$ has been completed in seven volumes; the first part of vol. viii., containing the results of the ledger of reference stars from the Algiers Meridian Catalogue, is nearly ready for the printers.

The 15-inch Grubb Refractor.—Observations of variable stars have been continued and 850 estimates of visual magnitude obtained. The working list remained the same as in the previous year.

Some of Herschel's fields of nebulosity were observed when the condition of the sky was found specially good.

Twenty-four occultations of stars by the Moon were observed :—

Disappearances	19
Reappearances	5

Time.—The error of the standard clock was determined as usual from observations with the transit instrument about once a week on the average.

Seismology.—The Milne-Shaw seismographs (both components) were in continuous operation during the year and the total number of shocks recorded was 192. The readings of the principal phases of the seismograms have been communicated as usual to the University Observatory, Oxford.

Daily observations of upper air conditions by means of pilot balloon flights have been continued in accordance with the programme of the India Meteorological Department.

The meteorological records and other routine duties have been maintained as in previous years.

Kodaikanal Observatory
(*Director, T. Royds, D.Sc.*)

Photoheliograms were obtained on 327 days, calcium flocculi plates on 324 days, calcium prominence plates on 303 days, *Hα* flocculi plates on 301 days, and *Hα* prominence plates on 282 days. One calcium flocculi plate for each day was sent to the Solar Physics Observatory, Cambridge, as in former years.

Under the auspices of the International Astronomical Union, prominence and *Hα* flocculi spectroheliograms were collected from other observatories whenever complete observations were not possible at Kodaikanal. The statistical data regarding prominences seen at the limb and by absorption on the disc are published in half-yearly bulletins. The inclusion in the publications of data for *Hα* prominences at the limb has been continued.

Daily character figures for solar activity according to *Hα* bright flocculi and *Hα* dark markings have been communicated to the Observatoire Fédéral, Zürich, for publication. In addition, character figures for the period 1923–28 were also derived and supplied at the request of Professor Brunner.

A Milne-Shaw seismograph has been received, which will replace the old Milne horizontal pendulum seismograph.

The 8-inch equatorial of the Madras Observatory has been transferred to the Kodaikanal Observatory.

Dr. Narayan has studied the nuclear moments of *In* and *Tl* and has published a note on the subject in *Nature*.

Mr. Muhammad Salaruddin has measured the *Hα* plates of three more years for the average change in the projected areas of *Hα* dark markings as they cross the Sun's disc.

Mr. G. V. Krishnasamy Iyengar, M.A., Reader in Mathematics at the Annamalai University, was permitted to do some research at Kodaikanal,

and he measured the time of rotation of *Hα* markings in the equatorial region. His results are set forth in a bulletin of the Kodaikanal Observatory.

A report on " Prominences, Areas at the Limb, Spectroheliographic, and on *Hα* Absorption Markings on the Disc " was sent to Dr. St. John, President of Commission No. 12 of the International Astronomical Union.

The Madras University has conferred the M.Sc. degree on Mr. A. S. Rao, research scholar of that University, who worked at Kodaikanal. His work on the spark spectra of lead has been published in *Kodaikanal Observatory Bulletin*, No. 91.

Dr. A. L. Narayan, the Assistant Director, was on leave for two months prior to Christmas.

Union Observatory, Johannesburg
(*Union Astronomer, Mr. H. E. Wood, M.Sc.*)

26½-*inch Grubb Visual Refractor.*—The year's work comprises :

Double Stars—2925 measures of double stars (including the 9-inch measures); 30 new pairs discovered.
Photographs of Double Stars—136 plates with multiple exposures.
Saturn's Satellites—5 measures of Mimas ; 6 measures of Enceladus.
Eros, 1930–31 *Opposition*—77 measures of position ; 89 measures of the elongation of Eros.
Photometry—149 plates of clusters and variables.

Franklin-Adams Star Camera.—During the year, 1084 plates were obtained with this instrument, distributed as follows :—

Short-Focus Lens	Minor planet regions and star maps ...	247 plates.
	Variable star regions	516 ,,
	Comets	30 ,,
Long-Focus Lens	Eros plates	186 ,,
	Photometry	84 ,,
	Minor planets	21 ,,

Comet Encke 1931 *a* was photographed on June 14 and observed up to July 17. Unsuccessful attempts were made to photograph the return of Comet Schorr 1918 III and Comet Neujmin 1913 III.

Photographs of Eros were taken with the long-focus lens from 1930 December 21 until 1931 May 17. One series was taken on the meridian with ordinary plates, and a second series through a yellow filter on yellow sensitive plates on the meridian, and also at large hour-angles east and west. The measurement of the plates is in progress.

240 measured positions of minor planets have been forwarded to the Astronomisches Rechen-Institut.

Occultations of Stars by the Moon.—The programme of the last few years has been maintained without alteration, and 167 occultations were observed during the year.

The results of the year's observations are as follows :—

	s	"
1931·2	9·8	5·4
·4	10·6	5·8
·6	9·9	5·4
·9	9·0	4·9

The second column indicates the time by which the Moon has arrived too early at any longitude, and the third column the distance the Moon is ahead of its tabular longitude.

A series of 47 occultations, observed by Mr. G. E. Ensor of Pretoria, has been reduced and the results forwarded to Professor E. W. Brown.

Union Observatory Circulars.—During the year Circulars Nos. 84 and 85 were distributed. 35 southern star maps were issued with these Circulars. Zones $-22°$, $-28°$, $-34°$ are now completed, and the two maps required to complete Zone $-40°$ are now in the hands of the Government printer.

The present state of the project is as follows :—

Maps already issued	423
Maps in hands of Government printer	18
Maps still to be prepared	115
Total	556

Miscellaneous.—Professor E. Hertzsprung, of Leiden Observatory, was at the observatory from 1930 December 2 to 1931 May 19.

Mr. H. van Gent, of Leiden Observatory, continued to use the Franklin-Adams star camera for the photographic investigation of variable stars until 1931 August 30 when he returned to Leiden.

The number of visitors to the observatory during the year has been 1230.

Adelaide Observatory
(*Director, Mr. G. F. Dodwell, B.A., Government Astronomer*)
(*For the Years* 1930–31)

The usual routine work, described in previous reports, has been continued. At the end of the year 1930 the observatory was brought into affiliation with the Adelaide University, though still remaining a State Government Institution.

An Observatory Committee was appointed by the University, and Professor Kerr Grant was appointed Honorary Associate Astronomer. A portion of the observatory grounds has been allocated to the University for their future use in the development of astronomical work. During the year 1931 a course of lectures on astronomy for surveyors was given at the University by the Director.

Following upon requests made by the International Latitude Commission, approval was given by the Government for latitude variation observations to be made in co-operation with La Plata Observatory, Argentine Republic. By the kindness of Dr. H. Kimura, President of the Latitude Commission,

the zenith telescope formerly at Mizusawa was made available for use at Adelaide, and was received in 1930 July. A special observing house was erected in the observatory grounds, and regular observations were commenced with the instrument in 1930 November, and have been continued throughout the year 1931.

A number of photographs of the Sagittarius region have been taken during the last two years with a Ross telephoto lens of 5 inches aperture and equivalent focal length of 40 inches.

Commonwealth Solar Observatory, Canberra, Australia
(Officer-in-Charge, Mr. W. B. Rimmer)

Solar Radiation.—Observations have been made daily since 1926 of the intensity of solar radiation received both at normal incidence and upon a horizontal area at the Earth's surface. In addition, the total radiation received on a horizontal surface has been photographically recorded throughout each day and the daily total derived. The standard instruments include pyrheliometers and pyranometers designed by Ångström and Abbot.

Sun Telescope.—This instrument, which was constructed mainly at the Ordnance Factory of the Department of Defence, has recently been completed and installed. The form of mounting is, in general, similar to that of the Einstein tower telescope at Potsdam. The mirrors are 18 inches in diameter, and the lens is 12 inches in diameter and of 43 feet focal length. With the instrument is associated a three-prism spectrograph by Hilger which gives a dispersion of 2·5 millimetres per angstrom at λ 4000. The following programme of work is arranged : Investigations of (*a*) the colour temperatures of the umbra and penumbra of sunspots, (*b*) the total intensity (equivalent breadth) and the structure of the Fraunhofer lines at the centre and limb of the Sun and in sunspots, (*c*) the rotation of the solar atmosphere at different latitudes, (*d*) motions of the vapours in sunspots. A Kipp & Zonen infra-red spectrograph is also being installed.

Sunspots.—Since 1925, observations and sketches of sunspots have been recorded on all suitable days. The Perth Observatory, Western Australia, co-operates by taking daily photographs of the solar disc and forwarding them to this observatory.

The Hale Spectrohelioscope.—This instrument has been temporarily mounted and tested. A permanent mounting is being arranged and a suitable grating obtained.

Atmospheric Ozone.—Measurements of the ozone content of the atmosphere were begun in 1929, using a Dobson spectrograph. On selected days a series of spectrum photographs has been taken throughout the day to check the constants of the instrument and allow of the calculation of the mean height of the ozone layer.

Luminosity of the Night Sky.—Observations were commenced in 1925 and have been carried on continuously, using the visual photometers supplied by Lord Rayleigh.

Atmospheric Electricity.—Atmospheric electric measurements made

include the following: (*a*) Potential gradient. Since 1926 a Benndorf electrometer has been used to record continuously the potential gradient of the atmosphere near the surface of the Earth. In addition to the study of the mean hourly variation, the values of the potential gradient are correlated with other physical phenomena which are also regularly observed. (*b*) Conductivity. Since 1929 October, observations of the electrical conductivity of the atmosphere have been made with a Gerdien apparatus. These measurements are combined with simultaneous potential gradient measurements to give values of the air-earth current. (*c*) Atmospheric nuclei and ions. Since 1930 July, measures have been made of the concentrations of intermediate and small ions, using ion counters designed and constructed at the observatory. In addition, an Aitken nuclei counter has been fitted with a cylindrical condenser in which the charged nuclei have been fractionally precipitated and separated from the uncharged nuclei. An ionisation chamber is in course of construction, and it is intended to work out a complete ionisation balance of the atmosphere at Mount Stromlo. Direct measurements of the mobility of atmospheric ions are being proceeded with. It is hoped to commence quantitative observations of cosmic radiation at an early date.

Atmospherics Investigations.—In 1930 September a radio research station was established at the observatory in conjunction with the Radio Research Board of the Council for Scientific and Industrial Research. The main purpose of this station is the investigation of the nature and distribution of sources of atmospherics, the characteristics of their propagation, and their relation to meteorological and other phenomena, especially with reference to their value in weather forecasting. The apparatus consists mainly of a cathode ray direction finder and a narrow sector continuous recorder. The operation of the direction finder is carried out in conjunction with a similar instrument at a station near Melbourne. Short-wave transmitting and receiving units have been installed at each station, so that the two observers are in direct communication and achieve simultaneity of observations.

Spectroscopy.—The determination of spectroscopic parallaxes is being continued, using the prismatic camera attached to the 9-inch Oddie refractor. Attention is being given to stars with bright-line and other peculiar spectra. In the laboratory, investigations have been made into the intensity and breadth of spectrum lines under varying conditions of excitation.

The Reynolds Telescope.—This is a 30-inch reflector which was presented to the observatory by Mr. J. H. Reynolds. It has been mounted in a steel dome 26 feet in diameter. The completion of this instrument, which has required certain modifications, has been protracted, as the construction and installation of the Sun telescope has demanded much attention. It is now approaching completion, and researches will be commenced on the colour indices and temperatures of southern stars. Photography of nebulæ in the southern sky will also be undertaken.

Time Service.—The Shortt Free Pendulum Clock (No. 31), by the Synchronome Co., London, has operated satisfactorily. Time-signals have

been recorded daily, and standard time supplied to Government departments, etc.

Meteorology.—A fully equipped meteorological station has been maintained, and complete records have been supplied to the Commonwealth Meteorological Bureau.

Publications.—Memoir No. 2 has recently been published and distributed. Two papers are in process of publication.

Melbourne Observatory
(*Director, J. M. Baldwin, M.A., D.Sc., Government Astronomer*)

During the year the staff has been still further reduced by the death of Mr C. J. Merfield, which occurred in January. His position as chief assistant has not been filled nor has any other appointment been made.

The regular observation of the list of fundamental stars published in the *Connaissance des Temps* for 1914, with the 8-inch transit circle, and of southern long-period variable stars with the 8-inch equatorial, has been continued. The latter observations have been published regularly in *Popular Astronomy.*

A series of 43 plates of Eros for parallax was taken with the astrographic equatorial between January 14 and February 13, several exposures being made on each plate. Plates were taken both east and west of the meridian.

Owing to no money being available for publication, it has been impossible to make any progress with the printing of the fourth and fifth Melbourne *General Catalogues* or with vols. iv and v of the *Astrographic Catalogue.* The monthly means of the hourly values of the magnetic elements for 1928 and 1929 were printed and have been distributed, and quarterly seismological bulletins have been issued as in previous years.

The time service and other routine duties have proceeded as usual.

Sydney Observatory
(*Director, Mr. James Nangle, Government Astronomer*)

Steady progress has been maintained in carrying out the programme, the principal part of which consists of the Sydney quota of the *Astrographic Catalogue.* Owing to unusually adverse weather, the transit observations of plate stars have been less in number than usual. Vols. ix and x have been completed, and it was hoped that the printing would have been carried out, and distribution of copies made, before the end of the year. However, though approval to print was given, the estimates have not yet been passed by Parliament. It is hoped that the printing will be done, and distribution of copies made, in the early part of 1932. Vols. xv and xvi are now in hand, and it is possible that they also may be printed and distributed before the end of 1932.

Without interfering with the work of the *Astrographic Catalogue*, 17 photographs of the position of the minor planet Eros, at the time of its last

opposition, were taken with the astrograph. The plates were forwarded to the Director of the Royal Observatory at the Cape of Good Hope.

The time service and other routine work of the observatory have been carried out satisfactorily. The routine work consists of quite an extensive service to the public, which is much appreciated.

Observations with the Milne seismograph have continued without a break. One hundred and fifty-six tremors were recorded. One of the records was of the disastrous earthquake which occurred in the Hawkes Bay district of New Zealand on the morning of February 3.

Public interest has been maintained in the observatory, the number of visitors during the year being 1009.

The Staff remains the same, Mr. W. E. Raymond being Chief Assistant, and Mr. W. C. Graham, Second Assistant.

The Dominion Observatory, Wellington, New Zealand
(*For the Year* 1930)

(*Director, Dr. C. E. Adams, Dominion Astronomer and Seismologist*)

The time service has been maintained, and the regular signals have been sent out. The signals have been transmitted daily. The total number of signals sent from the observatory was 1,931.

The usual method of recording radio time-signals has been to use the chronograph with the hand key. This method will be supplemented by an entirely automatic one, by means of the Marconi magnetic relay, which is now being installed.

Reception of Radio Time-Signals at the Observatory.—695 mean time-signals on 8 call-signs were received; also 85 scientific time-signals from Nauen.

Summer Time.—The Summer Time Act, 1929, provided for the time in New Zealand being half an hour in advance of New Zealand standard time, for the period beginning at 2 a.m., New Zealand standard time, on Sunday 1930 October 12, and ending at 2 a.m., New Zealand standard time, on Sunday 1931 March 15.

Occultations.—With the assistance of members of the New Zealand Astronomical Society resident in different parts of the Dominion, arrangements have been made for the observation of occultations of stars by the Moon.

Sunspots.—An enlarging camera for photographing sunspots is fitted for use with the Wellington City Observatory 9-inch equatorial telescope. The camera is used for any particularly interesting groups of sunspots. Observations are sent to Zürich, where they are used for international work in the determination of Wolf-Wolfer relative sunspot numbers.

Total Solar Eclipse of 1930 *October* 21–22.—A 19-foot coronagraph was lent by the Royal Irish Academy, and a 12-inch cœlostat by the Royal Astronomical Society. These instruments were erected at the Dominion Observatory, Wellington, and practices were undertaken. The expedition,

under the leadership of Dr. C. E. Adams, left Auckland in September and landed safely at Niuafo'ou. The expedition found a large American expedition already at the island, and received great assistance and every courtesy from the Americans.

The programme was as follows:—

(1) To photograph the solar corona in order to fill the gap that would otherwise exist in the series of corona photographs, especially as there would be no expedition from England to observe this eclipse.

(2) To photograph the flash spectrum and the spectrum of the corona.

This programme was carried out satisfactorily, and four photographs of the corona, two of the flash spectrum, and four of the spectrum of the corona were obtained. All the photographs are excellent.

Seismology.—During the year 327 earthquakes were recorded on the seismographs. The total number of earthquake shocks felt in New Zealand was 748.

The number of seismographs at the observatory has been increased. Besides the two Milne-Shaw and one Milne horizontal seismographs which have been in use for some time, the following equipment has been obtained: A Galitzin-Wilip vertical component instrument, three Wood-Anderson horizontal components, an Imamura strong motion horizontal and vertical components instrument, and an Ishimoto clinograph. At Suva, Fiji, there is a twin-boom Milne seismograph, the records of which are sent to the Dominion Observatory. Dr. T. A. Jaggar has presented one of his earthquake recorders to the observatory.

Mr. A. F. Bennett's Observatory, Leiston, Suffolk

The solar observations have been continued, and during the year some interesting comparisons have also been made as to the relative merits, for prominence work, of a diffraction-type spectroscope and one of the usual Evershed pattern.

The 6-inch Cooke refractor has also been used for visual work on planets, comets and other objects.

Eight lunar occultations were observed, including three obtained during the total eclipse of the Moon on 1931 September 26. The results have been communicated to the computing section of the B.A.A., for reduction and for publication in due course.

Rev. T. E. Espin's Observatory, Wolsingham

The mirrors of the 24-inch and 17¼-inch reflectors were successfully resilvered in the summer. The work of searching for new double stars and measuring them with the micrometer has been continued, and the results communicated to the Society.

Mr. Evershed's Observatory, Ewhurst, near Guildford

Nearly a hundred prominence spectra have been photographed and measured during the year, in continuation of a research on the solar rotation at high levels and to obtain further values of the general shift of the calcium lines H and K towards the red. The results again show an excess of angular velocity compared with that of the reversing layer, and an excess of shift compared with that predicted from relativity. The results over a series of years will be analysed to see if the angular velocity varies with solar latitude or with the sunspot period, as appears to be the case from a preliminary survey.

A number of spectra with iron arc comparison have been obtained at the Sun's limb, at the position angles of the poles and of the equator. The mean of 15 iron lines measured in these spectra shows that the general shift towards red is the same in these positions as in other latitudes, and is about 0·006 A. in excess of the Einstein effect. The equatorial plates have given values of the solar rotation, the results of which have been communicated to the Society.

High-dispersion spectra obtained with the liquid prism have been sent to the Solar Physics Observatory, Cambridge, for study with the recording microphotometer.

Spectroheliograms in $H\alpha$ light have been obtained on 65 days only, the weather during the year having been generally unfavourable for this work. In co-operation with the International Astronomical Union, such negatives as are required to complete the Kodaikanal series are sent there for measurement, and character figures have been sent to Dr. Brunner for incorporation in the bulletin published in Zürich.

The results of measures of the shifts of calcium, aluminium and iron lines in the solar spectrum have been communicated to the Society (*M.N.*, **91**, 260).

Some additions and improvements in the instrumental outfit have been effected during the year. A device for rotating the Sun's image through a measured angle on the slit of the spectrograph, and a new scheme for photographing simultaneously the opposite limbs of the Sun with the liquid prism spectrograph, have proved especially useful.

Mr. F. J. Hargreaves's Observatory, Kingswood, Surrey

Observations of the physical features of Jupiter were continued until April 22, and 431 central-meridian transits of markings were obtained. The relative smallness of this number was due partly to the continued bad weather and partly to the comparative quiescence of the planet's surface. A few observations have already been obtained in the new apparition.

Eighteen drawings of Mars were made at Kingswood, and the writer also made six drawings with the 18-inch reflector at Headley and, by the

kindness of the Astronomer Royal, was allowed to make two drawings with the 28-inch refractor at the Royal Observatory, Greenwich.

Five occultations of stars by the Moon were timed, out of a programme of twenty-three; the remainder were without exception obscured by clouds.

The construction of a " comparison-image " micrometer was begun in April, and the instrument has been in use since May 12. Details of the micrometer and of the results obtained with it were communicated to the Society in a paper published in *M.N.*, **92**, 72, 1931. Recently a modified form of the instrument, in which all loss of light is avoided, has been made and has proved successful, and details of it will be communicated in a further paper. A further modified form is about to be put into use for the measurement of the diameters of planets.

Mr. Newbegin's Observatory, Starween, Worthing, Sussex

The work of this observatory has been continued on the same lines as in former years, and the results indicate a slow progressive decline in solar activity for both prominences and sunspots. Observations throughout the year have been much hindered by bad weather, and in no week was it possible to secure records on more than five consecutive days.

Prominences.—Observations were made on 119 days, yielding 1145 prominences with a mean daily frequency of 9·61—a decline of 3·5 per day compared with 1930. The distribution was fairly uniform, with slight preponderances for the northern hemisphere and eastern limb. The greatest excess of prominences occurred in April and June, both months having 56 per cent. north of the equator.

Metallic prominences were recorded on 31 occasions, 16 being on the west limb, and only one was violently active. $H\alpha$ displacements numbered 33, the distribution east and west being equal. Only one prominence displaced the C line both ways simultaneously, but it was found that on two or three occasions displacements were seen in very high latitudes, one in particular being within 10° of the South Pole. Large prominences continue to be recorded, but they are much less extensive than a year ago. One was remarkable for covering no less than 56° of the limb and was one of the most extensive ever seen. It was observed on July 10 for four hours with but little change, and it is probable that it lasted for 14 days at least, as large prominences occurred in the same region on the east limb on July 23.

Sunspots.—145 observations of sunspots were made, the mean daily frequency being 2·1. Several days were spotless, and only one group reached naked-eye visibility. The principal decline in activity points to the southern hemisphere dying out sooner than the northern, the preponderance for the latter being 61·7 per cent. for the year. In November no spots were seen south of the equator, and only one in December.

Spectroscopic examination of all spots has been continued and some very fine motion forms have been observed, fuller details of which may be found in the *Journal of the B.A.A.*, **41** and **42**.

Mr. B. M. Peek's Observatory, Solihull, Birmingham

The usual programme, consisting of photometric observations of Nova Persei 1901, observations of the major planets, and lunar occultations, has been continued.

Shortly after Mars came to opposition at the end of January there was an improvement in the observing conditions, which enabled a fairly satisfactory amount of work to be done on the planet. The observation of Jupiter during the current apparition has suffered seriously from the exceptionally bad observing weather which obtained during the closing months of the year. The eight lunar occultations observed in 1930 have been reduced, and the results have been communicated to the Society.

Rev. T. E. R. Phillips's Observatory, Headley, near Epsom, Surrey

During the earlier part of the year the shutter of the dome covering the 18-in. reflector was replaced by a double shutter giving an aperture six feet in width. This is found to be a great advantage.

The usual work on planets and double stars has been continued, but the weather proved very unfavourable. Measures of several pairs of stars were communicated to Mr. F. J. Hargreaves for the purpose of comparing results obtained respectively with a filar micrometer and his recently designed and constructed comparison-image micrometer as described in *M.N.*, **92**, 72, 1931.

During the late summer Mr. P. M. Ryves was again in England and made observations of a number of variable stars as far as the seeing conditions permitted.

Dr. R. L. Waterfield has installed a 6-inch visual equatorial by Cooke in a separate building. This will be used as the guiding telescope for an F. 4·5 triplet of 6-inch aperture which has been ordered from Messrs. Cooke, Troughton & Simms.

The meteorological observations have been continued. Despite the bad summer, the total rainfall for the year was only 29·6 inches, which is nearly 3 inches less than the average for the previous 15 years.

Dr. W. H. Steavenson's Observatory, West Norwood

Observations were made on 109 nights during the year.

The 20-inch Hindle reflector was used almost exclusively for photometric work on faint variable stars and similar objects.

128 observations of 8 novæ were made, and some of the results for Nova Persei have already been communicated to the Society. 22 long-period and irregular variables have been observed for the Variable Star Section of the British Astronomical Association. Observations have been confined in each case to the period during which the star was fainter than $12^{m}\cdot0$.

296 such observations have been made and communicated to the Director of the Section.

Estimates of the comparative brightness of the satellites of Uranus were made on 15 nights. On two of these nights all four satellites were clearly seen, but in general the observations were confined to Titania and Oberon, which are nearly always easy objects in the 20-inch.

The planet Pluto was observed on 3 nights, and its brightness was compared with that of neighbouring stars of about the 15th magnitude.

During the winter of 1930–1931 some trouble was experienced through the dewing of the flat on damp nights. Since then a simple system of electrical heating has been introduced into the mounting of the mirror, and the temperature of the latter can be raised just sufficiently to prevent the deposition of dew without impairing the optical performance of the instrument in the slightest degree.

Mr. H. G. Tomkins's Observatory, Dedham, Essex

The year 1931 has been a very poor one for observational work at Dedham. The 24-inch Cassegrain has been in use whenever possible, but only 8 plates have been secured, owing to the bad weather and, unfortunately, illness in October. The plates obtained, however, indicate the improvement brought about by the introduction of the 6-inch Cooke refractor for guiding during the exposures, and give promise of good results if the weather will favour us with clear skies. In the meantime, the work of examining the plates already taken has been pushed on, positives have been made in a number of cases, and results obtained which I hope will enable a detailed report to be made to the Society shortly.

The lunar eclipse of 1931 September 26 was partly visible at Dedham. Clouds prevented observation until just after totality ended, but two photographs of the retreating penumbra were obtained. The earlier of them, taken at 22 hours, shows a good graduation of the shading over the western part of the lunar disc.

The mirrors were re-silvered as usual during the year, Brashear's formula being adopted as before.

NOTES ON SOME POINTS CONNECTED WITH THE RECENT PROGRESS OF ASTRONOMY

Minor Planets

Two hundred planets were discovered in 1931, as follows :—

Month and Designation	Day of Month	Magnitude	Discoverer
Jan.			
AA	10	15·0	KR
AB	11	16·5	MW
AC	14	...	D
AD	9	13·7	KR
BA	19	13·2	L
BB	27	16·5	GB
Feb.			
CA	9	13·5	KR
CB	14	14	KR
CC	14	14	KR
CD	10	16·5	GB
CE	10	16·5	GB
DA	22	13·9	WB
DC	24	16	GB
DD	25	14·5	MW
DE	25	15	MW
DF	25	15	MW
DG	25	14	KR
DH	24	14	GN
DJ	24	13·8	GN
Mar.			
EA	15	13·2	D
EB	12	14·0	KR
EC	13	14	MW
ED	13	16	MW
EE	13	16	MW
EF	13	14	KR
EG	14	16	MW
EH	15	15·0	KR
EJ	15	14	KR
EK	15	14·5	KR
EL	15	14·3	KR
Mar.			
EM	15	15	MW
EN	10	16	GB
FA	17	12·9	SW
FB	17	13·2	SW
FC	16	15·5	MW
FD	19	16	MW
FE	17	13·0	SW
FF	20	16·5	GB
FG	23	14·0	GN
Apr.			
GA	8	13·3	D
GC	8	14·5	KR
GD	9	14·5	KR
GE	9	14·2	KR
GF	12	14·2	FR
GG	12	13·0	FR
GH	8	15·0	KR
HA	22	14·0	SB
HB	24	13·2	J
HC	24	12·1	J
May			
JA	5	13·0	D
JC	5	16	MW
JD	10	14·3	KR
JE	10	14·5	KR
JF	13	13·2	J
JG	13	13·2	J
KA	23	13·0	D
KB	16	13·7	GN
KC	16	14	GN
KD	24	13·3	J
KE	21	13·3	J
Jun.			
LA	6	14	GN
LB	6	13·2	GN
LC	7	13·5	GN
LD	9	13·1	J
MA	19	13·0	GN
MB	23	13·5	GN
MD	18	13·5	J
Jul.			
OA	24	13·5	KR
OB	17	13·5	J
OC	16	13	GN
Aug.			
PA	7	13·0	J
PB	6	13·0	J
PC	14	13	J
PD	14	13	J
PE	13	13	J
PF	13	13	J
PG	14	14·1	J
QA	17	13	J
QB	24	...	D
Sep.			
RA	7	13·7	KR
RB	8	15·3	MW
RC	8	14·0	MW
RD	8	13·1	AS
RE	14	13·6	D
RF	15	13·1	D
RG	8	15	MW
RH	14	13·9	KR
RJ	14	14	KR
Sep.			
RK	14	13·8	KR
RL	13	13·7	GN
RM	15	14·8	KR
RN	15	14·0	KR
RO	15	16	MW
RP	15	16	MW
RQ	15	16	MW
RR	15	16	MW
RS	15	16	MW
RT	15	15·5	MW
RU	10	14·2	ES
RV	12	13·5	GN
Oct.			
TA	5	13	MW
TB	6	13·5	MW
TD	10	...	D
TE	8	...	PS
TG	11	...	FR
TJ	11	...	FR
TK	12	...	D
TL	8	13·3	PS
TM	15	...	D
TN	10	13·7	GN
TO	11	13·6	GN
TP	11	14	GN
TQ	11	13·5	GN
TR	5	14·5	KR
TS	5	14·5	KR
TT	5	14·8	KR
TU	5	14·5	KR
TV	5	14·6	KR
TW	5	14·4	KR

Month and Designation	Day of Month	Magnitude	Discoverer
Oct.			
TX	6	15·0	KR
TY	6	15	KR
TZ	6	14·6	KR
TB_1	6	14·0	KR
TC_1	6	14·8	KR
TD_1	6	15	KR
TE_1	6	14·7	KR
TF_1	6	14·5	KR
TG_1	6	15	KR
TH_1	6	15	KR
TJ_1	6	14·6	KR
TK_1	6	14·8	KR
TL_1	6	14·5	KR
TM_1	6	14·7	KR
TN_1	6	14·4	KR
TO_1	7	14·5	KR
TP_1	9	14·0	KR
TQ_1	9	14·8	KR
TR_1	9	14·8	KR
TS_1	9	14·6	KR
TT_1	9	14·6	KR
TU_1	9	14·7	KR
Oct.			
TV_1	9	14·4	KR
TW_1	9	14·3	KR
TX_1	9	14·5	KR
TY_1	10	14·0	KR
TZ_1	10	14·5	KR
TA_2	10	15	KR
TB_2	10	14·7	KR
TC_2	10	14·4	KR
TD_2	10	14·8	KR
TE_2	10	14·6	KR
TF_2	10	14·4	KR
TG_2	10	13·8	KR
TH_2	10	15	KR
UA	17	15·0	KR
UB	17	14·7	KR
UC	17	14·6	KR
UD	18	15·0	KR
UE	18	14·8	KR
UF	18	13·9	KR
UG	18	14·5	KR
UH	18	14·8	KR
UJ	18	14·2	KR
Nov.			
VA	2	...	D
VB	2	...	D
VC	2	...	D
VD	2	...	D
VE	2	...	D
VF	7	13·3	D
VG	2	15	KR
VH	2	15	KR
VJ	2	14·8	KR
VK	3	15·5	MW
VL	4	15·5	MW
VM	4	16	MW
VN	8	15	KR
VO	8	15·5	KR
VP	8	14·3	KR
VQ	8	15·0	KR
VR	15	14·7	KR
VS	15	14·6	KR
VT	15	14·3	KR
VU	15	15·0	KR
VV	15	15·0	KR
VW	6	13	GN
Nov.			
VX	6	12·5	GN
VY	9	13·8	GN
VZ	10	12·5	GN
WA	18	14·0	MW
WB	18	16·0	MW
Dec.			
XA	2	14·1	LB
XB	2	12·6	GR
XC	3	13·7	LB
XD	5	14·7	GR
XE	8	13·4	D
XF	8	13·5	D
XG	12	14·4	KR
XH	12	15	KR
XJ	12	14·9	KR
XK	12	16·5	MW
XL	8	13·0	D
XM	8	13·3	D
XN	3	13·2	GN

Objects announced as 1931 DB and 1931 JB were cancelled as erroneous.

The initials stand for : WB = W. Baade, Bergedorf ; SB = S. Beljawsky, Simeis ; GB = G. van Biesbroeck, Yerkes ; LB = L. Boyer, Algiers ; D = E. Delporte, Uccle ; J = C. Jackson, Johannesburg ; L = G. B. Lacchini, Turin ; GN = G. Neujmin, Simeis ; KR = K. Reinmuth, Königstuhl ; GR = G. Reiss, Algiers ; FR = F. Rigaux, Uccle ; PS = P. Shajn, Simeis ; AS = A. Schmidt, Algiers ; SW = A. Schwassmann and A. Wachmann, Bergedorf ; ES = E. Skvortzoff, Simeis ; MW = M. Wolf, Königstuhl.

Additional planets discovered in 1930 but not announced in time for last annual report : HN, MF, MG, SU at Johannesburg ; QS at Kyoto ; XD at Uccle ; YG, YH, YJ, YK at Yerkes.

The following identities have been established :—

285 = 1911 MQ, 785 = 1931 MC, 818 = 1929 JC, 926 = 1931 GB, 1909 FT = 1930 SL, 1924 TQ = 1931 RL = 1931 TH (this planet is of Hilda type, having $n = 458''$, and $\phi = 12°$), 1926 RH = 1931 TA, 1929 CM = 1931 GE, 1931 RJ = 1931 TF, 1931 RK = 1931 TC, 1931 TG = 1931 TA_1 ; also 1930 YC = *Jupiter's* satellite VI.

The following planets have received permanent numbers :—

1924 SL = 1930 HH = 1153, 1927 CB = 1154, 1928 BD = 1155, 1928 DA = 1156, 1929 QC = 1157, 1929 QF = 1158, 1929 RD = 1159, 1929 RL =

1160, 1929 SF = 1931 BB = 1161, 1930 AC = 1162, 1930 BA = 1163, 1930 FB = 1164, 1930 HM = 1165, 1930 MA = 1166, 1930 PB = 1924 SR = 1167, 1930 QA = 1168, 1930 QH = 1169, 1930 SQ = 1170, 1930 TA = 1913 SY = 1926 AD = 1171, 1930 UA = 1172, 1930 UB = 1173, 1930 UC = 1174, 1930 UD = 1907 AO = 1175, 1930 VE = 1176, 1930 WA = 1177, 1931 EC = 1178, 1931 FD = 1179, 1931 GE = 1907 YR = 1929 CM = 1180, 1927 CQ = 1181, 1927 EA = 1915*b* = 1182, 1930 DC = 1183. 1172, 1173 are the Trojan planets *Æneas* and *Anchises*.

The following planets have been named : 742 *Edisona*, 1038 *Tuckia*, 1057 *Wanda*, 1075 *Helina*, 1093 *Freda*, 1109 *Tata*, 1110 *Jaroslawa*, 1117 *Reginita*, 1137 *Raïssa*, 1152 *Pawona*, 1168 *Brandia*, 1176 *Lucidor*, 1177 *Gonnessia*, 1181 *Lilith*.

The following planets have interesting orbits : 1931 FE has period 3·713 years, $q = 1{\cdot}75$, $\phi = 16°$; 1931 RA has period 3·25 years, q 1·443, ϕ 20° ; 1931 UJ has i 25°, period 2·68 years.

Planet 657, missing since its discovery in 1908, was recovered at Johannesburg in 1930 and again observed in 1931 ; also 285, missing since its discovery in 1889, was lately proved to be identical with 1911 MQ. On the other hand, 1930 SQ (now numbered 1170) appears not to be identical with 330, as was conjectured in the last Council Note.

Kleine Planeten for 1932 contains the elements of all the planets that have received permanent numbers, and ephemerides of all that are in opposition in 1932.

A.N. 5841 contains new elements of No. 986 by Père L. Gauchet, S.J. Herr Rugemer discusses the perturbations of *Nestor* in *A.N.* 5756. M. Putilin gives new elements of 1036 *Ganymede* in *A.N.* 5764. No. 5833 contains elements of No. 472, including perturbations, by A. Rasdolkes.

433 (*Eros*) was diligently followed up till May ; not very much has yet been published, but mention may be made of two long series of observations. Professor J. Hartmann describes the visual and photographic observations at La Plata up to April 28 in *A.N.* 5815, and also discusses the light-variation, the range of which was much smaller than at the end of 1930. *A.N.* 5823 contains a fine series of observations by M. S. Mello e Simas, which extends to May 13.

A.N. 5780 contains some interesting observations of the shape of *Eros*, made by W. H. van den Bos and W. S. Finsen with the Johannesburg 26½-inch refractor, using a power of 1070. On the night of Feb. 3–4 the planet resembled a figure 8 ; this was confirmed on following nights, and the long axis of the figure was observed to go round in $5^h\ 17^m$, agreeing with the complete period of light-variation. An extended table of distances and position angles is given. The long diameter was 0″·18, or about 26 miles ; this appears to be the distance between the centres of the two portions (which were not separated, but joined by a ligament). *J.O.*, **14**, No. 3, contains a study of the light-variation of *Eros*, made at Marseilles in January and February. The period $5^h\ 15^m{\cdot}9$ is found, and it is noted that the increase of light was more rapid than the decrease.

N. T. Bobrovnikoff, whose paper on the origin and disintegration of

comets was noticed in the Council Note of 1930 February, contributes a paper on the origin of the minor planets to *P.A.S.P.* for 1931 October. He begins by quoting estimates of the total mass of the minor planets, and adopts the value, Earth/1000. He then points out many points of connection between comets and minor planets ; the mass of the great comet of 1882 was deduced as being at least Earth/250, from the fact that it did not suffer disruption while passing perihelion ; he notes that if a similar great comet had been broken up by *Jupiter* it would have given more than enough matter to form the entire family of minor planets.

The objection might be raised that he fixed the date of introduction of comets into the Solar System as about a million years ago ; the minor planets would then have a still more recent origin. The interval seems too short for the very wide dispersion of their orbits ; moreover, the fact that the four largest minor planets correspond so nearly with a term in Bode's sequence suggests that they are original members of the Sun's family.

The large number of discoveries in 1930 and 1931 shows that there is as yet no sign of approaching exhaustion. A glance at the column of magnitudes shows that nets of a finer mesh are now employed by our planet-fishers ; these catch small fish that could slip through the older nets.

A. C. D. C.

Comets

Observations of four comets, detected in previous years, were continued in 1931. Tempel (2) was observed at Yerkes till February, so that the observations cover an arc of six months ; this should lead to an accurate determination of the elements, which is fortunate, as the comet will be badly placed at the next two returns, and may not be seen for many years.

1927 IV (Stearns) was observed till the spring, four years after the discovery ; the distance from the Sun was $11\frac{1}{2}$ units, which establishes a record.

1930 IV (Beyer) was followed till the summer, and further observations are possible.

Schwassmann-Wachmann (1), which passed perihelion in 1925 May, and reaches aphelion in 1933, is likely to be visible round the entire orbit. It underwent a remarkable outburst of light in February (nearly one hundred-fold), though it was very remote from the Sun. There was a similar, but smaller, increase of light in December ; the magnitude changed from 17 to 16, and the diameter increased to 20″ (G. van Biesbroeck, *Pop. Ast.*, 1932 January). Dr. K. Reinmuth stated in *A.N.* 5779 that he had found cometary images on four plates exposed on 1902 March 4 and 5 ; the comet was of magnitude 12·0, and appeared as a nebulous patch, $1\frac{1}{2}'$ in diameter, with a faint nucleus and traces of a tail in P.A. 220°. Mr. L. E. Cunningham has found (*Harvard Card* No. 159) that the Reinmuth object is, in all probability, identical with Schwassmann-Wachmann (1). Both the position and the motion are very nearly satisfied. Since the comet was then not far from aphelion it must have been experiencing an outburst similar to that of 1931 February.

The first cometary discovery of the year was that of Encke's comet, this being its 38th observed apparition. The first announcement to arrive was from Mr. Bobone of Cordoba Observatory, Argentine ; he photographed it on June 21, giving its magnitude as 9. Mr. H. E. Wood had photographed it a week earlier at the Union Observatory, Johannesburg. He observed it on 21 nights, extending from June 14 to July 17 ; the positions are given in *Observatory* for August and September ; also in *A.N.* 5819. The comet was observed visually at the Dominion Observatory, Wellington, New Zealand, on July 5, 16 and 17, by Mr. I. L. Thomsen. He gave the magnitude as 8 on July 5, fainter than 9 on July 17. Mr. Wood gave it as 7 on June 14. The observations indicate that T was very close to June 3·1 U.T., which is 18 hours earlier than Mr. Matkiewicz's predicted value. He states that he did not apply perturbations by Saturn, so these may account for the discordance.

Comet 1931 *b* was discovered on July 16 by Mr. Masuji Nagata ; he is a native of Japan, now resident at Brawley, California, where he is engaged in fruit cultivation. He is an amateur astronomer, and was directing his telescope, a portable 3-inch refractor, to Neptune when he picked up this comet some three degrees to the east of the planet ; he informed the Mount Wilson astronomers, and they confirmed the discovery on the next night. Messrs. Zug and Berman quickly computed elements, which showed that the comet had passed perihelion about five weeks before its discovery ; it would probably have been visible to the naked eye at that time, as it was of the seventh magnitude when discovered. Observations were continued till the end of the year, though the comet was inconveniently placed low in the western sky ; it has now become a morning object, and is likely to be observed

Ref. No.	Year and Number of Comet	Name	T	ω	Ω	i
				° ′ ″	° ′ ″	° ′ ″
359	1884 III	Wolf (1)	Nov. 17·78313	172 42 24	206 18 31	25 15 40
561	1925 VII	van Biesbroeck	Oct. 2·97348	106 24 12	334 33 43	49 19 16
575	1927 III	Comas Sola	Mar. 22·1929	38 27 51	65 35 41	13 45 43
589	1930 II	Wilk	Jan. 22·30458	157 29 15	179 0 10	124 30 57
591	1930 IV	Beyer	Apr. 18·13176	24 37 44	116 23 34	71 58 28
593	1930 VI	Schwassmann-Wachmann (3)	June 14·195935	192 19 8	76 46 51	17 24 3
...	1930 *g*	Nakamura	Aug. 28·6748	62 47 24	229 19 10	4 9 53
594	1931 I	Neujmin (1)	Apr. 30·12	346 56 58	347 19 25	15 8 47
595	1931 II	Encke	P June 3·84757	184 53 47	334 39 15	12 33 55
596	1931 III	Nagata	June 11·64514	319 57 24	191 18 58	42 19 50
597	1931 IV	Ryves	Aug. 25·9447	168 15 36	101 28 24	169 16 0
...	1932	Wolf (2)	P June 26·88	177 55 12	260 19 55	23 48 25
...	1932	Tempel (1866 I)	P Nov. 1·8	172 36 0	233 54 0	162 41 0

for some months more. Observations of the first three months suffice to show that there is notable departure from a parabola, the period being in the neighbourhood of 267 years. It is not improbable that the comets of A.D. 574 and 1092 may be identical with it. Dr. Hind deduced elements for them from the rough Chinese observations that bear some resemblance to those of Nagata's comet ; also the dates are separated by about twice the period now found, and one-fifth of the interval from 574 to 1931 is 271½ years. The comet's orbit makes a close approach to that of Saturn, and a moderately close one to that of Jupiter, on the side preceding perihelion, so that perturbations would give rise to considerable variation in the period.

Nagata's comet underwent a remarkable outburst on October 6 ; Professor G. van Biesbroeck states (*Pop. Ast.*, November) that its light increased nearly a hundredfold, from magnitude 12½ to 8 ; after this he saw two tails, each 15′ long, in P.A. 40° and 110°, with nebulous matter between the two.

Comet 1931 *c* was found by Mr. P. M. Ryves, a Fellow of the Society, at Zaragoza, Spain, where he has resided for many years. One of his chief lines of work is observation of variable stars, and this year he made a series of observations of the star U Geminorum. Early on August 10 he detected a bright comet about two degrees from the star. Observation of position was difficult, owing to the bright twilight; but numerous positions were obtained up to August 19, after which the comet was lost in the Sun's rays. On August 14 Professor van Biesbroeck estimated its magnitude as 4, and saw a tail a degree long ; it became considerably brighter as it approached the Sun. Early orbits by Mr. L. E. Cunningham and by Dr. Bower and Miss Miller showed that its perihelion distance was about 0·074 units, which is the smallest observed since 1887, with the possible exception of the eclipse

Ref. No.	log *q*	Period in Years or Eccentricity *e* in Hyperbolic Orbits	Equinox	Computer	Reference
359	0·1964443	6·774262	1880·0	M. Kamienski	*Warsaw Observatory Circ.*, 10.
561	0·1948557	1·0004276 *e*	1925·0	G. van Biesbroeck	*A.J.*, 958.
575	0·2485958	8·52094	1925·0	Miss J. M. Vinter-Hansen	*Copenhagen Obs. Pub.*, 74.
589	9·8276048	24800	1930·0	R. Carrasco y Garrorena	*Madrid Anuario*, 1931.
591	0·3177557	1·0012935 *e*	1930·0	C. H. Smiley	*A.J.*, 962.
593	0·0049346	5·426894	1930·0	Miss P. Hayford C. M. Anderson, jun.	*Lick Bulletin*, 439.
...	9·61042	...	1930·0	K. Nakamura	*Kwasan Bull.*, 211.
594	0·18406	17·687	1931·0	A. C. D. Crommelin	MS.
595	9·5208347	3·285504	1931·0	L. Matkiewicz	*A.N.*, 5791.
596	0·019072	267·476	1931·0	A. C. D. Crommelin	*Obs.*, 1931 Dec.
597	8·87042	...	1931·0	,,	,,
...	0·39363	7·4575	1931·0	S. Kanda	*Tokyo Bull.*, 61.
...	9·99106	33·3	1932·0	B.A.A. Comp. Sect.	*B.A.A. Hdbk.*, 1932.

comet of 1893. Dr. Bower and Miss Miller thought at first that the orbit was notably hyperbolic, but they expressed doubt about this when the comet was reobserved in October. They noted that the comet had passed within some 13 million miles of Jupiter in the autumn of 1930 ; it remained for two months within half a unit of Jupiter, and must have experienced considerable perturbations, which have not yet been calculated. Professor van Biesbroeck recovered the comet on October 9 ; it had a diffused coma 3′ or 4′ in diameter, with central condensation, but no definite nucleus. Later in October he photographed a tail 45′ long in P.A. 120°—that is, nearly towards the Sun. On December 16 A. Schmitt photographed the comet at Algiers, giving its magnitude as 14·5. The orbit given is only approximate ; no exact orbit is yet to hand.

Comet 1931 *d* is the periodic comet Neujmin (1) 1913 III, which has a period of nearly eighteen years. It passed perihelion in April, but was then badly placed for observation. It was detected in September by Dr. Nicholson on plates taken with the 100-inch reflector at Mt. Wilson ; he subsequently found it on a plate exposed on August 20. The latest position published is on October 13. The magnitude was given as 15. Professor van Biesbroeck followed it till December 16, when its magnitude was $17\frac{1}{2}$. There was no distinct evidence of nebulosity at this apparition ; even in 1913 only two observers (Professors Wolf and Barnard) saw any coma ; it is not surprising that the much greater distance from Sun and Earth during the observations in 1931 prevented this from being seen. The orbit given in the table has been deduced by applying revised perturbations, based on the actual period of the comet, to the elements of the first apparition. It needs small corrections to give complete accord with the observations of 1931. The comet approached Saturn within 1·59 units at the beginning of 1918 March ; the perturbations by Saturn are much larger than those by Jupiter.

The orbit of 1930 VI is based on 53 observations, extending over nearly four months ; perturbations by the Earth and Jupiter have been applied. That of 1930 IV is from an arc of two years, but without perturbations.

Some of the images used in computing the orbit of 1930 *g* are very faint and somewhat doubtful ; the orbit will probably not be considered sufficiently certain to justify the assignment of a permanent number to the comet.

The predicted elements of 1866 I (Tempel) are based on the assumption that the comet of 1366 was identical with it ; the Computing Section of the B.A.A. has computed the perturbations from 1366 to 1932, but there is of necessity a considerable range of uncertainty.

A.J. 965 contains 119 hitherto unpublished observations of 29 comets, beginning with 1898 I, and ending with 1913 VI ; they were made by the late Professor E. E. Barnard, and have been reduced by Professor G. van Biesbroeck, Miss M. Calvert and Mr. A. Pierce.

Kwasan Observatory Handbook contains a useful catalogue of cometary orbits from the earliest times to the end of 1930, compiled by Professor I. Yamamoto. The elements are given to the third decimal of a degree ; a separate list gives the years in which the various periodic comets were observed. There are some errata ; thus comet 1927 IX (Skjellerup) is

wrongly identified with 1846 IV (De Vico); but no catalogue of comets exists that is quite free from errata.

A.N. 5826 contains a paper by S. Vsessviatsky on the origin of the comets of short period; he shows that there are grave difficulties in ascribing them all to capture by the giant planets, and revives the suggestion of R.A. Proctor that, in some cases at least, they may be due to eruption from these planets.

Erratum in last Council Note, p. 376, third line from bottom:
For 1930 II *read* 1930 I. A. C. D. C.

Stellar Structure

The investigations on stellar structure during the past year have largely concentrated on the work of Milne of the previous year. Sir Arthur Eddington has not found it possible to accept Milne's ideas; his criticisms are set out in *Zeit. für Astrophys.*, **3**, 129. Milne's work has been developed along several lines during the year. It has been shown by different methods by Eddington (*M.N.*, **91**, 440), B. Strömgren (*M.N.*, **91**, 466), Cowling (*M.N.*, **91**, 472) and Russell (*M.N.*, **91**, 739) that the model proposed by Milne, in which a perfect gas envelope surrounds a degenerate gas core of very high temperature, opacity being uniform throughout, cannot exist. Some modification of Milne's model became necessary, and one such modification was supplied by the discovery made by Miss Swirles (*M.N.*, **91**, 857) that the opacity of a degenerate gas is much smaller than that given by the laws valid for a perfect gas. Other modifications made necessary by the high central temperatures have been investigated by Chandrasekhar (*M.N.*, **91**, 446) and M'Vittie (*M.N.*, **92**, 55).

In Milne's work there was included the suggestion that a nova outburst might result from a rapid collapse of a star occurring when its luminosity passes through a critical value. In view of this suggestion, the experimental results as to the observations of Nova Pictoris published during the year have been of peculiar interest. These show that a decrease of the radius does actually appear to have occurred, and to that extent confirm the theory (see *Observatory*, **54**, 140, 193).

The bearing of Milne's work on the opacity difficulty encountered in the theory of gaseous stars has been investigated in numerical integrations by Miller (*M.N.*, **91**, 984) and Biermann (*Zeit. für Astrophys.*, **3**, 116). It appears that no serious difficulty is added to that already existing. Milne has also discussed the opacity difficulty (*Zeit. für Astrophys.*, **3**, 253), and suggests that it is actually illusory.

In *Ap. J.*, **73**, 250, Atkinson has put forward certain suggestions as to the origin of stellar energy. He suggests that stellar energy is generated by the synthesis of hydrogen into more complex elements, due to the passage of protons into the nuclei of atoms already existing. The theory is incomplete at present, but it opens a valuable line of attack. The temperature demanded for such an atomic synthesis is of the same order of magnitude as Eddington predicted.

Finally, mention should be made of the work on stellar hydrodynamics and stability by Thomas (*M.N.*, **91**, 122, 619) and by Rosseland (*Pub. Obs. Oslo*, No. 1), who was able to confirm certain of Jeans's results.

A good, though somewhat conservative, review of recent work on the subject has been given by Russell in *M.N.*, **91**, 951. T. G. C.

Solar Activity

Sunspots.—The sunspot activity continued to decline during 1931, the average daily area of spots being one-half that of the year 1930. The mean daily number of spots also decreased in about the same ratio. No spots were seen on the Sun's disc on about 40 days. There were, however, three groups of spots of considerable extent, the largest of which, with central meridian passage on February 20 and in latitude 6° N., had a maximum area of nearly 1900 millionths of the Sun's hemisphere. The second group, which developed on the disc after the time of its central meridian passage on January 12, increased to 1200 millionths before passing round the west limb. The third, with central meridian passage on March 15, rose to a brief maximum of 1000 millionths. Three other groups reached 500 millionths. The times of central meridian passage and latitudes of these largest groups in order of appearance are as follows :—

Jan. 12·5	7° N.	Mar. 15·4	4° N.
Feb. 20·6	4° S.	May 20·5	16° S.
Feb. 20·7	6° N.	Nov. 26·9	10° N.

The following groups of sunspots, designated by their respective times of central meridian passage, were active on one or more occasions as observed spectroscopically at one or two of the following observatories: Greenwich, Meudon, Mount Wilson, Mr. Newbegin's observatory at Worthing.

(1) Jan. 12·5 (2) Feb. 20·6 (3) Mar. 11·9 (4) Mar. 15·4 (5) Apr. 7·6 (6) Apr. 16·5 (7) Apr. 17·4 (8) May 13·3 (9) June 8·7 (10) July 10·5 (11) Aug. 16·5 (12) Sept. 7·6 (13) Nov. 7·6

Nearly all of these sunspots were associated with the transitory appearance of brilliant *Hα* flocculi recorded directly with the spectrohelioscope or on spectroheliograms, or represented by very bright reversals of *Hα* observed by A. M. Newbegin at Worthing. In the case of No. 13, the eruption of bright hydrogen on November 6 was seen to take place suddenly within two minutes of time (*Observatory*, 54, 305, 1931). The eruption connected with No. 9 on June 14 was observed at Worthing to be associated with the bright reversal on the Sun's disc of b_3 due to Fe^+. Spots Nos. 2, 3, 6, 10, 11 and 13 were associated with dark hydrogen flocculi or filaments with maximum radial velocities of the order of 50 km./sec. No. 7 was associated on April 21 with rapidly changing " motion forms " of the *Hα* line, extending at one time 6 A. to the violet (*Journ. B.A.A.*, **41**, 475, 1931). No. 8 was the centre of a sequence of dark flocculi on May 10 with maximum radial velocities of the order of 100, 50, and 30 km./sec. respectively.

It may be added that terrestrial magnetic activity was distinctly less than

in 1930, there being seven disturbances of storm range $D \geq 30'$ or H or $V \geq 150\gamma$ recorded at Greenwich (Abinger) during 1931 as compared with twenty-three for the previous year. H. W. N.

Prominences, 1931.—Compared with the year 1930, the mean daily areas of calcium prominences in 1931 show a decrease of 3 per cent., of hydrogen prominences a decrease of 20 per cent., and of hydrogen dark markings on the disc a decrease of 38 per cent. All other forms of prominence activity also show a decrease, except the daily numbers of prominences, which indicate an increase of 8 per cent.

The mean daily areas of calcium prominences in square minutes of arc, as derived from Kodaikanal spectroheliograms, are as follows :—

	North	South	Total
1931 January to June	2·18	2·06	4·24
July to December	2·13	2·08	4·21

The above figures indicate nearly equal activity in the northern and southern hemispheres and in the two halves of the year, in contrast to the situation in 1930. A peak in the latitudes 40°–50° is the principal feature in the latitude distribution of prominences, which is very similar in the northern and southern hemispheres. The mean daily numbers were 14·0 and 13·3 for the first and second halves of the year respectively, being an increase of 8 per cent. over 1930, whilst areas show a decrease of 3 per cent.

Prominences exhibiting metallic lines numbered 25 as against 38 in the year 1930. There was only one observed during the second half of the year, and none was seen above latitude 18°·5. Displacements of the hydrogen line in the chromosphere and prominences observed during the year numbered 245, as against 276 in the previous year. Of the displacements 150 were towards the red, 80 towards the violet, and 15 both ways simultaneously. Bright reversals of the $H\alpha$ line in the neighbourhood of sunspots numbered 300, while those observed in the previous year were 450. Displacements of the $H\alpha$ line on the disc totalled 37 as against 55 in the year 1930. Of these displacements 27 were towards the red, 8 towards the violet, and 2 both ways simultaneously. D_3 was observed as a dark line on 282 occasions as against 435 during 1930.

The mean daily areas of prominences projected on the disc as absorption markings in hydrogen light was 2140 millionths of the Sun's visible hemisphere, representing a decrease of 38 per cent. on the previous year. In the southern hemisphere there is a well-marked minimum between latitudes 20° and 40° in both halves of the year.

The mean daily areas of hydrogen prominences in square minutes of arc are as follows :—

	North	South	Total
1931 January to June	0·74	0·63	1·37
July to December	0·76	0·63	1·39

These areas are about 33 per cent. of calcium areas. The curve of distribution in latitude of $H\alpha$ prominences is generally similar to that of calcium prominences. T. R.

Solar Research

General Structure of the Sun's Atmosphere and the Formation of Fraunhofer Lines.—The attack on the general problem of stellar atmospheres has continued actively throughout the year, and, as is made inevitable by our observational limitations, the chief way of approach is still provided by the Sun. The new quantum theory continues to throw more light on results of the classical electron theory, and is also giving important information on the manner in which atoms and light quanta react with each other. In observational work the technique of photographic photometry is progressing rapidly; and with the stimulus of these extensions of knowledge on both theoretical and practical sides, the complex mathematical theory of the formation of Fraunhofer lines is being given a considerable amount of attention.

H. H. Plaskett (1) in a long paper describes the careful measurement of the contours of the green triplet of magnesium in the Sun's spectrum. Observations were made at the centre of the disc and at two points at certain distances out towards the limb. An excellent account is given of the photometric technique, together with a discussion of the errors of measurement which includes, it might be mentioned, a valuable criticism of the Moll microphotometer. It has been known for many years that there are marked variations of the Fraunhofer lines from one part of the disc to another, and theories have predicted the nature of this variation. Plaskett, therefore, applies his observations to testing theories of atmospheres where the distinctive features are (*a*) pure absorption, (*b*) pure scattering, (*c*) combined absorption and scattering (Eddington's model). Although its application to these measurements is not entirely without difficulty, theory (*c*) gives by far the best fit with observation. The need for more extended measures at a greater number of places on the disc seems clear. An apparent discrepancy between Plaskett's contours and those obtained earlier by Minnaert and Mulders is shown by the latter (2) to be due simply to a misreading of their paper; the agreement actually is very good. Woolley (3) has criticised one of the conclusions reached by Plaskett concerning the effect of collisions of the second kind on relative intensities in multiplets. The contours of the solar magnesium triplet have also been measured by Righini (4). The differences between his results and those of Minnaert and Mulders at Utrecht are of the order of 10 per cent., the Utrecht lines being deeper except at the centre. Righini's method has been criticised by Plaskett (*loc. cit.*, p. 903).

Pannekoek (5) seeks to work out more exactly than has yet been done the contours of Fraunhofer lines produced in certain model stellar atmospheres, first of constant composition and later with concentration of neutral atoms varying with electron pressure. As is usually found, the computed line centres are blacker than those generally observed in solar or stellar spectra. The possible causes of this discrepancy are discussed. In a later paper (6) this difficulty is attacked in another way. If, as it appears, atomic energy levels are not perfectly sharp, there is a possibility that an atom might be able to absorb light of one frequency and re-emit light of slightly different

frequency. This will lead to a redistribution of energy within an absorption line. The question has been discussed by Woolley (7), and now Pannekoek works out its effect on the central intensities of Fraunhofer lines. It appears that it does not increase the residual intensities at the line centres sufficiently to account for more than a small part of the difference between theory and observation. Minnaert and Slob (8) have used Pannekoek's work to calculate the total intensities of Fraunhofer lines as a function of the number of absorbing atoms, and confirm earlier results on the course of the curve expressing this relation.

Minnaert and Mulders (9) discuss the part played by radiation damping in producing the breadths of Fraunhofer lines, and conclude that with lines of greater intensity (Rowland number > 6) the breadths are chiefly due to this factor. Using intensity measures made at Utrecht, the numerical values for the radiation damping are calculated to be of the order of ten times the value of the formula $\frac{8\pi^2e^2}{3mc\lambda_0^2}$ given by the classical electron theory. A consideration of the green and violet magnesium lines in the light of the newer quantum theory shows this to be not impossible. Pannekoek (10), in a paper dealing with the rôle of collisions in the formation of Fraunhofer lines, also computes the damping constant from data given by a spectrum of α Cygni. The result has nineteen times the classical value, and is compared with the figure just mentioned for the Sun. Since it would be expected that collisions would be more important and the constant therefore greater in the Sun, it is concluded that, so far as these data are concerned, collisions are comparatively unimportant in energy interchanges of atoms in the solar atmosphere.

The recently published theory of Weisskopf and Wigner indicates the necessity, when calculating an absorption coefficient arising from a certain energy change in an atom, of considering the transition probabilities in both the upper and lower quantum states which are involved, instead of, as before, those in the upper state only. Unsöld (11) has endeavoured to test this theory by application to the Balmer series in the solar spectrum. Using an earlier estimate of his own for the number of hydrogen atoms in the two-quantum state lying above 1 cm.^{2} of the photosphere, together with the transition probabilities for the hydrogen atom worked out by Slack and Sugiura, he calculates the hydrogen contours and compares with observation. There is agreement for $H\alpha$, but starting at $H\beta$ and rapidly growing from thence down the series, there is a discrepancy which is attributed to the pressure effect. The application of the work of Weisskopf and Wigner is shown, however, to have effected an improvement over older theory.

A neat way of studying the variation of an absorption line with the number, N, of atoms involved is pointed out by Woolley (12), who measures widths in the B band, due to oxygen in the Earth's atmosphere, in the spectrum of the Sun at varying altitudes during the day. There is a variation of width proportional to $N^{\frac{3}{8}}$ instead of $N^{\frac{1}{2}}$, as would be expected on Unsöld's theory. The same writer (13) discusses the difficulties raised by the differences between multiplet intensities predicted by the quantum theory and

those observed in the Sun, and traces their source to a failure of Unsöld's method rather than of the Russell-Adams calibration. In another paper (14) he deals with the interlocking of triplets of absorption lines and shows that under certain conditions the line widths are unaffected.

Chromosphere.—Menzel publishes an important paper (16) in which he endeavours to find exactly to what layer of the Sun's atmosphere Milne's chromospheric theory may be applied. Milne supposed the reversing layer to be in local thermodynamical equilibrium, while the chromosphere is in monochromatic radiative equilibrium, *i.e.* collisions are an essential feature of the former layer, while they are negligible in the latter. Using an expression for atomic absorption derived from the wave-mechanics, together with recent observational data, Menzel is led to some variation of Milne's interpretation of the theory as applied to the Sun. The pressures and density gradient which are derived for a chromosphere fully supported by radiation turn out to be very low, and it is suggested that Milne's theory applies only to the outermost chromospheric layers. A satisfactory and complete theory is apparently yet to be found. The investigation makes it appear likely that there is a large excess of hydrogen in the Sun's outer layers.

Woltjer (17) has worked out the effect of the resistance offered by the gases of the solar atmosphere to the outflow of Ca^+ ions in the chromosphere. The calculated density of the chromosphere, taking this into consideration, is $0{\cdot}2 \times 10^{-16}$ gm./cm.^{3} in place of an earlier value, $0{\cdot}5 \times 10^{-13}$.

Sunspots.—The molecular bands in sunspot spectra taken at Mt. Wilson have been investigated by Richardson (20). Evidence is found for the presence of C_2, *TiO*, *MgH*, *CaH*, *SiF*, *AlO*, *AlH* and *ZrO*. *MgH* is found on the disc, but not *TiO*. In the spot spectra the presence of H_2 is uncertain. From the band intensities, temperatures are deduced for sunspots and the reversing layer in satisfactory agreement with values deduced in other ways. R. W. B. Pearse (21) gives evidence for the presence of *SiH* in sunspots, and Miss Moore (22) has revised and extended identifications in the solar spectrum between λ 2975 and λ 6635, and in the spot spectrum between λ 3894 and λ 6635. Lines of *Lu II* have been identified for the first time. The relative behaviour of line intensities on the disc and in spots can be explained satisfactorily by physical and thermodynamical theory, while it is found that the amount of material per cm.^{2} above sunspots is greater than elsewhere on the surface.

The question of oxides and hydrides in the Sun's atmosphere, and particularly in sunspots, is dealt with by Piccardi (23). Experiments with a magnesium arc, where pressure and temperature conditions could be made very like those in a sunspot, showed spectra of *MgO*, *MgH* and the *OH* group, as well as atomic *Mg* and *H*, existing together. In sunspots, *MgII* and the *OH* group have been observed, but not *MgO*, and this is thought to be due to the composition of the Sun's atmosphere (chiefly excess of hydrogen) rather than to particular conditions of pressure and temperature.

Following a paper published in 1930, Unsöld (24) continues work in which an upper limit for the fall of temperature in a sunspot is calculated from thermodynamical considerations, assuming the Sun's atmosphere to consist predominantly of hydrogen. The calculated minimum spot temperature is 3720° K., with a disc temperature in the neighbourhood of 5130° K. Comparison with observation suggests that the minimum temperature is actually very nearly attained.

Prominences and Corona.—Considering the motion of a prominence as that of a particle under a central force, and neglecting terms involving $\frac{d\theta}{dt}$, Bobrovnikoff (31) evaluates from observational data the repulsive forces acting on prominences. There are many irregularities, and frequently a constant central force will not represent the observations satisfactorily. Pettit (32, 33) employs simultaneous observations with a spectrohelioscope in $H\alpha$ light and spectroheliograph in K_2 light, to show conclusively that the major features of prominences in the two lines are the same. There are, however, noticeable differences of detail, especially in active prominences, which he suggests are due to local electric fields. Data concerning the height of hydrogen absorption markings above the Sun's surface are obtained by Royds (34) from measurement of their period of rotation, as given by Kodaikanal spectroheliograms for 1926–1929. At the limb their height lies between 28″·0 and 33″·5 above the level given by $H\alpha$ spectroheliograms, which is itself found to be 6″·3, or 4590 km. above the photosphere. Lockyer (35), with the aid of recent observations, has confirmed a relationship between prominences and the form of the corona.

Lyot (37), following up his 1930 work, has succeeded in taking direct photographs of the inner corona from the summit of the Pic du Midi. This was possible only by taking the most careful precautions to eliminate scattered light by screens and filters and then observing only on days of exceptional transparency.

A suggestion put forward by Rosenthal that the coronal spectrum is due to helium has been criticised by Hylleraas (38), who makes closer investigation and finds that there is no quantitative agreement to support this proposal. There is, on the other hand, some evidence for the presence of oxygen in the corona, for Hopfield (39) points out that within the accuracy of measurement the coronal line λ 6374·2 coincides with the oxygen line λ 6374·29.

Eclipses.—Freundlich and his co-workers have commenced publication of the important results of the observations made at Takengon, Sumatra, by the Potsdam expedition to the solar eclipse of 1929 May 9. Particular interest has been taken in their measurement of the deflection of light in the Sun's gravitational field (43). Two series of photographs were taken, one with a horizontal camera of 8·5 m. focal length and the other (yet to be published) with the astrographic telescope. With the horizontal instrument four plates were obtained, while elaborate precautions were taken to avoid errors arising from variations of atmospheric refraction during totality, from

the application of an erroneous scale correction and from distortion of the gelatine on the plate. It was unfortunate, but naturally quite unavoidable, that the 17 or 18 stars whose images could be measured were distributed unsymmetrically about the Sun, most of them being on the eastern half of the plates. The final result for the deflection at the Sun's limb is 2″·2. Rediscussion of measures made by the Greenwich observers in 1919 and the Lick observers in 1922 leads to higher values than those previously given, and apparently to agreement with the Potsdam figure. (Attention might be drawn to an instructive diagram on p. 197, *loc. cit.*) It is thought that the excess over 1″·75, the theoretical deflection, is real and not simply the result of observational error. An account of this work was given by Freundlich at the 1931 December meeting of the Society (45), and in the following discussion Dyson and Eddington expressed an inclination to continue to regard 1″·75 as correct. Jackson (46) has also published a commentary on this work.

Von Klüber (41, 42) investigates photometrically the coronal images on the photographs taken primarily for measurement of the light deflection. The plates were standardised prior to development and were measured with a Hartmann microphotometer. Errors are discussed, and the resulting light intensities are given in the form of isophotal contours. The distribution of light is more uniform than the appearance of polar streamers, etc. might suggest. The total brightness at the same eclipse, and also at that of 1930 October 21, was measured by Stetson, Arnold, and Johnson (48) by comparison with a standard lamp, using a special Macbeth illuminator. The intensity at mid-eclipse was 0·15 foot-candles in 1929 and 0·378 in 1930. It is believed that, after correcting for the varying amount of inner corona covered by the Moon, there is evidence for increased total brightness at sunspot maximum.

Grotrian (40, 44) gives the results of observations of the corona with three spectrographs, two glass and one quartz. He gives wave-lengths and estimated intensities of 15 coronal lines (see also (47)), and similar data for 128 lines, mainly of metallic origin, given by a large prominence which happened to lie across the slits of the spectrographs. Displacements in these lines showed radial velocities of the order of 100 km./sec. The spectra were also compared photometrically with ordinary sunlight. It was deduced that between λ 3400 and λ 6500 the intensity distribution of coronal continuous spectrum agrees within $0^{m}\cdot1$ with that of the Sun. The wave-length of maximum blackening was independent of height within the corona. The evidence is held to favour the suggestion that the continuous coronal spectrum arises by pure light scattering, chiefly by free electrons, although it is pointed out that this view contains certain difficulties.

The work of Wright and Curtis (51) on interference in the corona has already been published elsewhere and was referred to in last year's Note.

Instrumental and Observational.—Hale (55, 56) has continued his description of the spectrohelioscope and the uses to which it may be put. Sufficient confirmation of the value of this instrument, if any be needed, may be found

in the work of Pettit, already mentioned, and that of Newton (57, 58, 59), where its possibilities in collaboration with other instruments are well illustrated.

Evershed (60) has continued his study of the red-shifts of lines in the Sun, and publishes measures for the region near H and K. After removing the relativity displacement there still remain small shifts of obscure origin which demand further observations of the highest accuracy.

Miss Moore and Meggers (61) have given evidence for the absence of rhenium from the Sun's atmosphere. Sjöström has published (66) a 12-year series of measurements of solar radiation made at Upsala.

Other Work.—Two or three other papers of varied nature may be mentioned. Ferraro (70, 71) has made some investigation into the question of the emission of charged particles from the Sun—a matter intimately connected with the problem of terrestrial magnetic storms and auroræ.

Hess and Pforte (72) give the results of new measures of the highly penetrating radiation to which so much attention has been paid during the past few years. They find a clear maximum of intensity at midday, and deduce a solar component amounting at most to 5 per cent. of the total radiation. The absorption coefficient of this component is estimated at about $\mu = 5 \cdot 10^{-4}$ cm.$^{-1}$ water.

No attempt has been made in this Note to deal with all the papers on solar research published during 1931. It is hoped, however, that the list of references below is fairly complete.

R. O. R.

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Stellar Spectroscopy

Spectrophotometry.—The calibration, through the comparison spectrum, of early stellar spectrograms, taken without any standardising exposures, has been attempted by several observers. Keenan (1) has measured the relative intensities of 18 titanium lines in the Yerkes comparison spectra with this object in view. He finds that measures of total hydrogen absorption in stellar lines calibrated in this way agree within 15 per cent. with results obtained from the ordinary sensitometer curves of standardised spectra.

Observations of *Na* and Ca^+ doublets and *Mg* triplets (sharp and diffuse series) in stellar spectra by Shajn (2) have yielded some interesting results. Central line absorptions are considered, and one of the most noticeable features is the small intensity difference between lines belonging to the same multiplet. The difference is smaller than that observed in laboratory emission spectra, and than that predicted by theory for emission lines. Individual stars of similar spectral type show differences between intensity ratios for the same multiplets. A good example is that of the sodium

D lines in α Orionis and α Tauri, the intensity difference being negligible in the first star and very well marked in the second. The intensity ratio H/K, for both absorption and emission lines, also deviates considerably from observed laboratory values and theoretical predictions.

The contours of emission bands in the spectra of novæ and Wolf-Rayet stars have been studied by Beals (3) in relation to the hypothesis of continuous ejection of atoms from the stellar surface. On this hypothesis the contours depend on the frequency distribution of velocities of ejection, and almost any observed contour can be accounted for by suitable assumptions regarding this distribution. Actual observations of emission bands in several stars yield flat-topped contours, implying an approximately Gaussian velocity distribution with considerable spread, and tending to support the ejection theory of the origin of such bands.

Sampson's spectrophotometric method of determining stellar temperatures has been applied by Georgette Maulbetsch (4) to 142 stars in the north polar region, using a Schilt microphotometer with a rectangular diaphragm covering an interval of about 30 to 40 A. Five regions of the spectra were measured, and a discussion is given of the resulting gradients and temperatures. Her results indicate that temperatures obtained in this manner may be used satisfactorily for statistical work.

Microphotometric tracings of a very faint star (van Maanen's No. 1166) in *h* Persei, of photographic magnitude 13·44, by Yngve Öhman (5), show many similarities to the companion of o^2 Eridani, and support Oosterhoff's suggestion that this star is a white dwarf.

Dufay (6) has shown that errors in spectrophotometric measures due to differential atmospheric absorption should be corrected by adjusting each observed value of the magnitude difference separately, rather than by adding a correction to the computed gradient.

Pannekoek (8) has continued his theoretical investigation on the contours of absorption lines, and Woolley (9) on the interlocking of triplets in absorption lines.

Axial Rotation.—Work on stellar rotation, as evidenced by the resulting " dish-shaped " line contours, has been continued by Struve and Elvey (11). They summarise the previous theory, methods, and results, and produce additional evidence from observations on eclipsing binaries. Such systems afford an independent method of computing axial rotation since, when in partial eclipse, the primary has one limb covered and rotation will produce an asymmetrical effect on line contours. Such asymmetry of the lines is well marked in the case of Algol, where the contours agree with predicted shapes. The resulting computed value of the axial rotation also agrees well with the value obtained from the usual dish-shaped contour measured when Algol is out of eclipse.

Struve (12) suggests that axial rotation should be regarded as a major independent factor, to be combined with temperature, pressure, and abundance of atoms, in defining the appearance of a stellar spectrum. He gives an analysis of various causes which tend to produce broadening of stellar

lines, and also points out an additional effect which should be observable in rapidly rotating stars. This is an absolute magnitude effect due to the lowering of surface gravity in such stars, resulting in increased ionization.

Kreiken (13, 14) has continued his work on the relation between period of rotation and semi-diameter, based on the Struve-Elvey rotational velocities and Hertzsprung's hypothetical semi-diameters. He finds ultimately a relation of the form

$$\log P = 1{\cdot}5 \log D - 0{\cdot}5 \log M - 0{\cdot}62$$

where P is the period of rotation, D the diameter at distance $\pi = 0''{\cdot}1$, and M the mass. More observational material is, however, required to confirm his results.

Axial rotation as a possible cause of emission lines in stellar spectra is referred to in the following paragraph.

Bright-Line Stars.—A suggestion as to the possible origin of bright lines in B-type stars has been made by Struve (15). It is known from observation that in stars of this type which have double bright lines placed symmetrically over absorption lines, the latter are always extremely flat and broad. This is suggestive of rapid axial rotation, a hypothesis which would be in agreement also with the strong proportionality of line-width to wave-length observed in many cases. Struve suggests that very massive stars (such as those of type B) if rapidly rotating will become unstable and form lens-shaped bodies, with the ejection of matter round the equator. This ejected matter will form a nebulous ring round the star and give rise to the emission lines—double if the axis of rotation is greatly inclined to the line of sight, single if this inclination is small. Payne and Maulbetsch (16) have examined bright-line stars in the Scorpio-Centaurus and Pleiades clusters from the point of view of this theory. Their conclusions do not support the rotational theory, which is not fully in accordance with apparent line widths in the stars measured. In particular, the proportionality of width to wave-length appears to vary for different elements. The authors also find a difficulty in reconciling the theory with various statistical properties of Be-type stars, and suggest that a physical rather than a mechanical explanation must be sought for the origin of emission lines in these stars.

A note by Adams and Joy (17) on bright calcium lines in stars of types G to M discloses some interesting differences between giants and dwarfs. In the latter, bright lines (if present) are narrow, sharp, and very strong, placed centrally on the broad [H] and [K]. In giants, on the other hand, bright lines are usually asymmetrically double, with the red component stronger than the violet, and separated by very strong central absorption lines.

Detailed studies have been made by M'Laughlin (18) of two bright-line stars (25 Orionis and π Aquarii), in which variations of emission intensity ratios are correlated with radial velocities from both emission and absorption lines. The relation is well shown in his curves, and indications also appear of short-period variations superimposed on the main period. The presence

of such short-period changes in the emission spectra may account for discrepancies between M'Laughlin's observations of π Aquarii and Lockyer's suggested period of 1194 days (19). It is shown by M'Laughlin that the variations of the emission ratio of the two components of a double bright line cannot be caused by the relative movements of these components and the central absorption line.

The star HD 216057 Lacertæ has been noted by Lockyer (20) as showing bright $H\beta$ and possibly $H\gamma$, previously unrecorded.

Selective Absorption and Colour Excesses.—The interpretation of the colour excesses observed in stars of types B and A has given rise to some discussion. The reality of selective absorption in interstellar space, implying a correlation between distance and colour excess, is doubted by Miss Payne and others, who prefer to attribute the observed reddening to causes inherent in the stellar atmospheres. Caroline Anger (21) has investigated the colour excesses in the cluster *h* Persei, and concludes that they cannot be used as an indication of space reddening. She has also examined (22) the cluster N.G.C. 663, which shows the effect very strongly. From the distribution of colour excesses in this cluster she favours Wallenquist's hypothesis of absorbing clouds around the cluster rather than selective absorption depending on distance. Schalén (23), however, using Miss Anger's published values of the colour excesses in N.G.C. 663 in combination with distances based on his own parallaxes, still finds a definite correlation between distance and colour excess. He considers that selective absorption by a medium extending to a distance of about 2000 parsecs is the most probable explanation.

Seares and Mary Joyner (24, 25) find that data in the case of selected area No. 40 suggest the presence of a selectively absorbing cloud at a distance of about 600 to 1200 parsecs. Lois Slocum (26), in a study of five selected areas in the Milky Way, finds that those stars for which data are available confirm Trumpler's value of selective absorption depending on distance.

In a theoretical investigation of the subject, Öpik (27) shows that several hypotheses of origin in the stellar atmospheres would be capable of explaining the phenomenon, but that the most probable hypothesis is that of selective interstellar absorption.

With a view to throwing further light on this controversy, Elvey (28) has made a detailed examination of 153 stars of types A and B. He concludes that two factors are concerned in producing the observed reddening. One is selective scattering in space, and the other the total absorption of the hydrogen lines. Overlapping of the wings of Balmer lines in the violet would cause reddening, and this effect should be related to absolute magnitude since it is proportional to the Stark effect. If colour excesses are first corrected for distance, using Trumpler's relation together with Edwards's spectroscopic parallaxes, the resulting corrected values show good correlation with the total hydrogen absorption.

Spectroscopic Parallaxes.—The correlation between hydrogen-line intensities and luminosity in the stars of types B and A has been investigated

at several observatories, and forms a useful method of determining the spectroscopic parallaxes of such stars. The relation, as shown in some galactic clusters, has recently been studied at Harvard by Miss Anger and Miss Payne (30, 31). Rasmuson's cluster parallaxes were used as a basis for the luminosities, which were finally calibrated by the values in the Ursa Major cluster. The authors find that absolute magnitudes can be more accurately determined from hydrogen-line intensities than from spectral type alone ; and that although the dispersion of line intensity on absolute magnitude is probably real, it is small enough to justify the use of this method for spectroscopic parallaxes. They use the method to determine the mean distances of five galactic clusters, and also the individual parallaxes of stars in the Scorpio-Centaurus cluster. The latter results are in good agreement with Rimmer's spectroscopic parallaxes for the same stars, except in the cases where the absolute magnitude is faint.

Statistical.—The luminosity curves for stars of different spectral types have been investigated by Strömberg (32 to 34) by a valuable method which utilises peculiar motions, parallactic motions, and radial velocities. The frequency distributions of absolute magnitudes are treated separately for groups of stars within small ranges of spectral type, and it is found that the shape of the luminosity curve for one group is reproduced in adjacent groups with only small changes of detail. This continuous run of the curves from group to group affords some evidence of the reality of the less well-defined features. In the case of later type stars, definite maxima appear in the frequency curves, which suggest the classification of these stars into four groups, viz. bright giants, normal giants, faint giants, and dwarfs. The mean absolute magnitudes of these groups will, of course, depend upon spectral type.

The A-type stars show only two maxima, corresponding to supergiants and normal stars. In the B-type stars there are indications which appear to justify the division of the supergiants into two or even three separate groups, including one with a mean absolute magnitude as bright as $-8{\cdot}0$.

Gerasimovič (35) has applied Strömberg's method to the early B-type stars. His results differ considerably in detail from those of Strömberg, probably because the latter did not utilise peculiar motions which, in the case of B stars, are much smaller than the parallactic motions and are liable to introduce serious accidental and systematic errors. Schilt (35*a*) has shown that the reality of Gerasimovič's maxima is indeterminate, since similar but smoothed curves fit his material equally well.

Radial Velocities.—The use of objective prism instruments for radial velocity work would possess great possibilities of valuable results for faint stars if once the initial difficulty were overcome of obtaining a standard from which to measure absolute wave-lengths. A summary of various attempts in this direction is given by Millman (37, 38), together with an analysis of the probable errors of results from the different methods. The author reaches the conclusion that the absorption-screen method (using

neodymium chloride) is the most promising yet suggested, and the one least liable to systematic errors.

A study of the spectrum of ζ Tauri by Hazel M. Losh (39) deals mainly with the radial velocity changes in this star. She concludes that these changes cannot be explained fully by orbital motion, though the long-period variation is probably due to this cause. Pulsations may contribute to velocity changes, but only as secondary causes, since the computed value of $a \sin i$ is about 100 times that of an average Cepheid and ω is 326° instead of being in the neighbourhood of 90° as might be expected by analogy with the Cepheids. Many of the important velocity variations remain unexplained at present.

The spectrum of β Libræ (suspected to be a spectroscopic binary by Lee and Mellor) has been studied by M'Laughlin (40), who considers that the velocity is probably constant, though a definite decision is difficult owing to the character of the spectrum.

The radial velocity variations of 25 Orionis and π Aquarii (18) have been referred to in the paragraph on bright-line stars.

The orbits of numerous spectroscopic binaries have been determined during the year, and mention of the more important ones is made in the list of references given at the end of this note (41).

Miscellaneous.—Several advantages could be obtained by the use of gratings instead of prisms for stellar spectrographs, especially for work in the red and infra-red regions, owing to the normal dispersion and greater range of spectrum obtainable. Up to the present, however, they have not been extensively used. A new type of plane grating stellar spectrograph has been described by Merrill (42), designed to overcome some of the constructional difficulties, particularly flexure, found in earlier instruments. Preliminary observations with this instrument at Mount Wilson indicate the efficiency of its behaviour and its value in problems concerned with the yellow or red region (such as the interstellar D lines of sodium), or in the infra-red up to 8700 A. For radial velocity work with such a grating, the higher wave-lengths yield more accurate results owing to the greater linear displacement, and measurements by Miss Burwell show that even with the low dispersion of 66 A. per mm. the probable errors of radial velocities obtained from the red region are only about ±1·0 to ±5·0 km./sec. according to the quality of the spectrum.

The spectra of B-type stars form the subject of a special study by Struve (43), who has measured 13 typical stars covering the whole range of subgroups from O9 to B8. A list of wave-lengths, probable origins, and intensities of absorption lines in these stars is given, which is more complete than any hitherto published. The list contains 379 lines between λ 3820 and λ 4924, of which about 150 are new. Contours of helium lines show that these are highly susceptible to Stark broadening; but the intensities show some unexplained variations, particularly for the ratio, singlet/triplet, in *HeI*.

The presence of manganese lines in stellar spectra has been investigated by Morgan (44). The star α Andromedæ is typical of that class which

contains manganese lines, and was for some time considered peculiar in this respect. Morgan, however, has found 13 other stars of types B5 to A0 with similar spectra. The lines are apparently due to *MnIII*, and their behaviour seems to be entirely normal.

The star B.D. −18° 3789 has been found by Morgan (45) to show variations of intensity in the *Cr* and *Eu* lines. The period is the same ($3^d \cdot 18$) for both, but the *Cr* and *Eu* appear to be always opposite in phase. The spectrum resembles that of α^2 Canum Venaticorum.

H. Spencer Jones (46) gives the wave-lengths, probable origins, and intensities of 66 lines in the spectrum of η Carinæ in the region 3938 A to 6562 A. A large number of these are Fe^+ lines, including many forbidden lines, thus confirming the previous work of Merrill on the spectrum of this star.

Accurate laboratory wave-lengths of oxygen and nitrogen lines in the stellar region 3880 A to 4705 A have been measured by Beals (47), using high-dispersion gratings at South Kensington and at Victoria. The results are given for 52 *O* lines and 38 *N* lines within this region.

Two forbidden lines of neutral oxygen at wave-lengths 6300·0 A and 6363·9 A have been discovered by Merrill (48) in a very faint star (estimated magnitude 10·5) near B.D. −6° 4772 and 4773. These lines had previously been observed only in nebulæ and novæ, but appear to be outstanding features in the spectrum of this star. D. L. E.

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Stellar Motions

Since the last Council note on the proper motions of the stars (*M.N.*, **90**, 457, 1930) a large number of investigations on stellar motions have appeared, and in the present note no attempt has been made to do more than give brief accounts of several of the more interesting studies under the headings : General Investigations, Solar Motion and Star-streaming, and Galactic Rotation.

General Investigations.—In *Contributi Astronomici*, vol. ii, Nr. 26, 1931, of R. Osservatorio di Capodimonte, G. Bemporad publishes a list of photographic proper motion measures of 254 stars between magnitudes 8 and 12, in the Carte du Ciel region, $7^h\ 15^m$, $+47°$. The interval is 33 years, and the estimated probable error in each co-ordinate is about 0″·007. The results show that the complete re-photography of the zones for the measurement of proper motions could now be undertaken with complete confidence in the intrinsic value of such an investigation.

The Yale proper motions for declinations between $+50°$ and $+60°$, corresponding to the Harvard and Helsingfors A.G. zones, have been treated statistically by J. Schilt and Ida Barney in *A.J.*, **40**, 168, 1930. They find that the declination of the solar apex is much higher for stars of type G5 to K than for stars of types A and F. There is also a well-marked difference in right ascension, the value being smaller for the early type stars.

In *Bulletin* No. 108 (1930) de l'Observatoire Central de Poulkovo, J. Lehmann-Balanowskaja gives the proper motions of 1433 stars in the region of the open cluster N.G.C. 6885 (20 Vulpeculæ) ; the measures are based on two pairs of plates, with intervals of 12 years and 28 years respectively. The deduced proper motion of the cluster is extremely small, +0″·001 in each co-ordinate.

In a short note, *A.J.*, **40**, 83, 1930, M. S. Kovalenko refers to the uncertainty of deriving the mass-ratio of a binary from measures made at only two epochs and the assumption of the Boss value for the proper motion of the centre of gravity of the system, and he urges the desirability of utilising photographs taken at, at least, three well-separated epochs, the proper motion of the centre of gravity being inserted in the equations of condition as an extra unknown. From 6 plates of 70 Ophiuchi taken at the Sproul Observatory between 1914 and 1928, he derives the mass-ratio of this system to be 0·45.

In *B.A.N.*, No. 189 (1930), J. J. Oort gives a statistical study of the stars of high velocity selected according to proper motion. The space velocities of the stars are first corrected for solar motion, the parallaxes being taken from Schlesinger's Catalogue (1924). Oort applies the term " high-velocity star " to one with a corrected velocity equal to or greater than 63 km./sec. He gives two tables, one showing the numbers of stars for different visual magnitudes m and different values of the function H ($\equiv m + 5 \log p$), and the other showing the percentages of high velocities for different values of H.

In *A.J.*, **41**, 17, 1931, B. P. Gerasimovič contributes a study, based on the proper motions of the galactic Cepheids, of the period-luminosity law which has an important bearing on the estimation of the distances of extra-galactic objects. On the one hand it has been asserted that Shapley's parallaxes should be increased seven or eight times, and on the other that the period-luminosity curve has a discontinuity at the point corresponding to a Cepheidal period of 10 days. In this paper, Gerasimovič utilises the most recent measures of the proper motions of 50 galactic Cepheids, and radial velocity measures of 32 of these objects. The radial velocities show

that these stars are amongst the slowest moving known, and that the solar motion is about 14 km./sec., and the mean peculiar velocity about 12 km./sec. The inclusion of the galactic rotation term in the equations has a negligible effect on the value of the solar velocity. From the parallactic and the τ-components of the proper motions, Gerasimovič derives the mean parallaxes for two groups separately—one, with periods less than 10 days, the other with periods greater than 10 days. The final zero-point correction to the period-luminosity curve is deduced as $+1^{m}\cdot0$, which means the reduction of all distances based on Shapley's period-luminosity curve by the factor 0·63. This result disposes of the drastic reduction in distances, previously suggested, based on the characteristics of the Cepheids. As regards the other suggestion concerning the possible discontinuity of the period-luminosity curve, the author's results and those obtained by Shapley from his study of the Magellanic variables are practically identical when allowance for the shift of the zero-point has been made ; the same empirical relation between period and luminosity thus holds for stars of periods less than or greater than 10 days.

Lund. Medd., Ser. II, No. 60, 1931, contains a paper, on the same subject, by Knut Lundmark. After observing that the novæ and Cepheids in the Andromeda nebula give practically the same distance for this stellar system when the absolute maximum magnitudes of galactic novæ and the period-luminosity law of the galactic Cepheids are used, the author discusses the influence of a possible absorption in the Milky Way zone on the zero-point of the period-luminosity curve. Discussing also the proper motion material used by R. Wilson and B. P. Gerasimovič, he concludes that a correction of $+0^{m}\cdot6$ to the zero-point of the curve will be more than counterbalanced by a correction of $-0^{m}\cdot85$ due to spatial absorption. Thus the final zero-point correction becomes very small. The existence of an absorption correction is considered more than probable owing to the discrepancy found in the distance of the Small Magellanic Cloud as derived from the data associated with the galactic Cepheids and the distance obtained by other methods. The author has added very useful tables giving the known data (proper motions, radial velocities, periods, etc.) of the galactic Cepheids.

In *Contributi Astronomici d. R. Specola di Merate*, No. 14, 1931, G. Cecchini discusses the absolute magnitudes of the galactic Cepheids, using, first, the data in his general catalogue of stellar parallaxes (No. 4 of the publications of the same observatory), and, secondly, general results based on proper motions (No. 5). The parallaxes give an inconclusive result as regards any possible shift of the zero-point of Shapley's curve, whereas the second part of the investigation indicates that Shapley's absolute magnitudes require a positive correction of $+1^{m}\cdot1$, in agreement with Gerasimovič's work.

In *Ap. J.*, **71**, 163 (*Mt. Wilson Contribution*, No. 395, 1930), G. Strömberg describes a method of determining the distribution of stellar absolute magnitudes from the observed distributions of angular velocities (τ-components) and linear velocities, the distribution of the latter being inferred from the radial velocities. The analysis leads to an integral equation involving the three distribution functions, which is solved by a method of successive

approximations. The method is applied to the Boss stars of spectral types K and M (*Ap. J.*, **71**, 175 ; *Mt. Wilson Contribution*, No. 396, 1930). For the Ko–K2 stars, four distinct maxima occur at absolute magnitudes −1·8, +0·2, +2·9 and +6·7, the proportions of stars in the four groups being 9, 78, 12, and 1 per cent. respectively. Strömberg designates these stars by the terms " supergiants," " ordinary giants," " subgiants," and " dwarfs." In the interval K3–K9, three maxima occur at absolute magnitudes −2·4, −0·1, and at about +7·0, the proportions being 19, 78, and 3 per cent. Among the M stars only supergiants and ordinary giants appear, the frequency maxima being at −1·6 and −0·1, and the proportions 44 and 56 per cent. Strömberg suggests that the several frequency maxima correspond to separate states of stable conditions in the stars, which ought to be of importance in theories dealing with the problem of stellar evolution.

In *Ap. J.*, **72**, 111 (*Mt. Wilson Contribution*, No. 410, 1930) Strömberg develops the method, outlined above, in connection with the parallactic motions, and in the succeeding pages applies the theoretical formulæ to the Boss stars of type M. The results are : two maxima at absolute magnitudes −4·5 and 0·0—supergiants and ordinary giants; the relative proportions of stars in the two groups are 9 and 91 per cent. respectively. In *Ap. J.*, **73**, 40 (*Mt. Wilson Contribution*, No. 481, 1931) he considers the Boss stars of type K. The Ko–K2 stars show maxima at absolute magnitudes −2·5, +0·3, +2·7 and 6·1, in good agreement with the results based on the τ-components, the proportions being 14, 78, 7 and 1 per cent. The stars of type K3–K9 give three maxima at −4·5, −0·1 and 6·7, the proportions being 7, 91 and 2 per cent. The small proportion of dwarfs in all these investigations is, of course, due to the particular character of the material on which they are based.

Considering now the Boss stars of types F and G, Strömberg derives in a similar manner (*Mt. Wilson Contribution*, No. 430) the distribution of absolute magnitudes of these stars, and obtains for types Fo–F9 three distinct maxima at −3·5, +1·5 and +3·2, and for types Go–G9 three maxima at −3·0, +0·5 and +3·0. His frequency curves show a complete absence of stars of both F and G types having absolute magnitudes around −1·0. The B and A stars have been discussed similarly (*Ap. J.*, **74**, 342 : *Mt. Wilson Contribution*, No. 440, 1931) in six groups, each group showing two or three maxima. The author considers that the reality of the various maxima in all these investigations is extremely probable, as there is a continuous run from one spectral group to another, without any overlapping of the groups.

Solar Motion and Star-streaming.—In *Mount Wilson Contributions*, No. 412, 1931, A. van Maanen discusses the proper motions of some very faint stars. From photographs of forty-two of the selected areas, including about 60,000 stars, with an interval of about eighteen years, 122 stars were found with proper motions exceeding 0″·04 per annum, most of them being in magnitude between 11 and 19. The ratio of the proper-motion stars to the total number investigated in the regions increased from 0·07 per cent. in

low galactic latitudes to just over 1 per cent. in high latitudes. From an analysis of the motions the solar antapex was found to be in right ascension $6^h\ 43^m$, declination $-30°$. Several previous investigations had placed the antapex at least 10° farther south; in particular, the fainter Wolf stars of large proper motion give the declination nearly $-40°$, although the faint Ross stars have been shown by van Maanen to give practically the same declination as in his present paper. It should be remembered, however, that these investigations are concerned with the nearest of the faint stars. From the τ-components of the proper motions, van Maanen derives the mean parallaxes of these stars: for different groups, they range from 0″·009 to 0″·004. While, of course, no conclusion can be drawn with respect to the individual parallaxes, the discovery, in van Maanen's list, of exceptionally faint stars, say of absolute magnitude +18 or +20, does not look very promising.

An important paper by R. E. Wilson and H. Raymond (*A. J.*, **40**, 121, 1930) deals with the space motions of 4233 stars. Counts were made of the number of velocities, in divisions of 4 km./sec. Owing to stream motion and asymmetry the condition of random velocity is not even approximated, but by means of a series of Maxwellian functions the observed velocity distribution was closely represented. As the solar motion derived from any set of stellar motions depends largely on the relative number of stars with different motions, the data were roughly weighted according to the velocity frequencies; the co-ordinates of the solar apex and the solar speed are found in the mean to be: $A = 275°{\cdot}5$, $D = +31°{\cdot}8$, $V_0 = -18{\cdot}8$ km./sec. Preferential motion is most marked among the A, F, K giants and K, M dwarfs, and least evident among the B and M giants. The progression in stellar velocities with increasing redness is a phenomenon confined to the main spectral sequence. The asymmetry in the stellar motions is well shown by the progressive increase in the values of the solar motion derived from groups of stars of increasing velocities. The radial velocities have been treated by the authors for the problem of galactic rotation, and the result is in good agreement with other investigations of this character. The proper motions treated in a similar way give a much smaller value for the rotation, and the discordance is attributed partly to the incompleteness of the rotation hypothesis and partly to systematic errors in the data.

In a paper, "A New Determination of the Solar Apex" (*A. J.*, **41**, 143, 1931), F. K. Edmondson employs a method of Herschelian simplicity, using the data of Schlesinger's *Catalogue of Bright Stars*. The numbers of positive and of negative proper motions in right ascension are counted for each hour of right ascension, and the algebraic difference, reduced to a percentage of the total number of stars in each hourly group, is plotted against right ascension. The curve cuts the axis near 6^h and 18^h (corresponding to the right ascensions of the antapex and apex respectively), and to fix the points more accurately, smaller subdivisions in right ascension are made in the neighbourhood of 6^h and 18^h. A similar procedure is adopted for the components of the proper motion in declination. The position of the apex is $A = 272°$, $D = +33°{\cdot}6$. The solution from the radial velocities gives $A = 266°{\cdot}9$, $D = +30°{\cdot}4$, $V_0 = 20{\cdot}8$ km./sec.

In *M.N.*, **91**, 563, 1931, R. D. H. Jones investigates the constants of the star-streams in different galactic zones whose mean latitudes are 0°, ±20°, ±43°, ±69°, utilising the proper motions of Boss's *P.G.C.* The data are thus the same as in A. S. Eddington's paper (*M.N.*, **71**, 4, 1910), but the method of subdividing the celestial sphere is different. Jones analyses the drift curves for each zone. The chief feature of the results is a decrease in the velocity of Drift I from 1·73 at the galactic equator to 1·41 in galactic latitude 69°. For the whole sky, the position of the solar apex is in excellent agreement with Eddington's result, but Jones's value for the solar velocity is somewhat higher.

In a second paper (*M.N.*, **91**, 990, 1931) Jones utilises the results for the different regions in the four galactic zones to investigate the space distribution of the Boss stars. He considers, first, the form and characteristics of the drift curves, omitting all proper motions less than 0″·02, and, second, the distribution of the magnitudes of the proper motions irrespective of position-angle, following in each case methods developed previously by W. M. Smart. Jones finds that the values of k in Dyson's density formula, $\frac{A}{r}e^{-h^2k^2r^2}$, increase steadily with galactic latitude, and are sensibly uniform for each region in the same galactic latitude.

In *M.N.*, **90**, 743, 1930, W. M. Smart investigates the subject of star-streaming in relation to spectral type. The stars in four of the Cambridge proper-motion regions were photographed at the Radcliffe Observatory through a blue and a yellow filter, and from the measurement of the diameters of the resultant images, the stars were separated into three groups, I (spectral types B, A, F), II (G–K5), and III (K5 – M). The distribution of proper motions in position-angle of the stars in each of the groups is given, and the main features of the results are that I and II show very much the same kind of distribution as is found in the two-stream theory, but that III exhibits to a marked extent a separation into two distinctive groupings, the more prominent of which (roughly in the direction of the antapex) has a much greater lateral spread than is consistent with the appropriate Drift I in the part of the sky concerned.

Galactic Rotation.—As B. Lindblad and J. H. Oort have shown in developing the theory of differential galactic rotation, there should be a definite relationship between the coefficient A in the galactic rotation and the ratio of the two axes of the velocity ellipsoid lying in the galactic plane. In an investigation (*M.N.*, **90**, 503, 1930), B. Lindblad studies this relationship, using the same groups of stars for the two sections of the work. The analysis leads to—(i) values of the rotational constants in good agreement with previous determinations; (ii) a period of revolution of about 150 million years at the Sun's distance from the galactic centre; (iii) a value of 6500 parsecs for the Sun's distance from the centre; (iv) a mass of the galactic system 10^{11} times the Sun's mass.

In *B.A.N.*, **189**, 192, 1930, J. H. Oort derives the motion of the Sun with respect to the interstellar calcium and also the galactic rotation effects.

The material used is from a paper by J. S. Plaskett and J. A. Pearce (*M.N.*, **90**, 243) to which reference was made in the Report of the Council for 1930 (*M.N.*, **91**, 398, 1931). Oort bases his work on the assumption that there is likely to be no systematic error in the calcium cloud radial velocities, and consequently the K term usually inserted in the equations in statistical work of this kind can be equated to zero. Assuming also the longitude l_0 of the axis about which rotation occurs to be 327°, Oort derives the solar motion and the value of $\bar{r}A$ with probable errors five or six times smaller than those emerging from the work of Plaskett and Pearce.

In *M.N.*, **90**, 233, 1929, F. W. Dyson analyses the proper motions of Boss stars in the three spectral groups Bo–B5, B8–Ao and A2–A5. The principal feature of the solution is a third harmonic, with a coefficient very much larger than that in the second harmonic arising from the differential rotation. Dyson thinks that this third harmonic arises from the peculiar motions of the stars, rather than from systematic errors in the observations. He also gives a short discussion of the corrections which the data suggest should be applied to the luni-solar and planetary precessions and to the motion of the equinox.

In a series of papers [*C.R.*, **188**, 236 (1929), **188**, 1086 (1929), **189**, 1378 (1930) ; *M.N.*, **90**, 516, 789 (1930)] H. Mineur agrees that for the distant stars the study of stellar motions points to a differential rotation effect about an axis in galactic longitude $l_0 = 325°$ as suggested by Lindblad and Oort, but believes that for the nearer stars (belonging to a local " cloud ") the evidence indicates a rotation of the cloud about an axis in longitude 243°, the cloud as a whole, in addition, sharing in the general rotation of the galaxy. The author accounts for the third harmonic found by Dyson (see above) on this hypothesis, and also for the distribution of the positions of the solar apex derived from various groups of stars.

In *M.N.*, **90**, 690, 1930, R. O. Redman investigates the radial velocities of 200 giant stars of type K, of visual magnitude 7·0 to 7·5, lying within 10° of the galactic equator. The dwarf stars of the original observing programme were eliminated by means of proper-motion or spectroscopic criteria. Different solutions for the solar motion and galactic rotation give a high value for the declination of the solar apex, and a value of l_0 20° to 50° higher than that usually ascribed ; the value of $\bar{r}A$ agrees satisfactorily with other estimates. The author remarks that it is significant that in all work on late-type stars the value of l_0 agrees better with the vertex of the stream-motion than with the value ascribed to the galactic centre. In a second paper (*M.N.*, **92**, 107, 1931) the author repeats the work, using now about 400 K giants, and arrives at substantially the same results as in the first paper.

In a paper in the *Proceedings of the Imperial Academy, Tokyo* (vol. vii, 294, 1931), M. Kaburaki suggests that the low space-velocities of the stars in the widely dispersed clusters of Perseus and Scorpio-Centaurus are simply the effects of the galactic rotation. Using the radial velocities and the proper motions of these stars, he applies the usual statistical methods to derive the solar motion and the rotational constants, with results in very good agreement with the accepted values of these quantities. According

to Rasmuson the distances of the stars in these two groups range from 50 to 120 parsecs, and it would thus appear that the characteristics of the motions of these stars must be attributed to galactic rotation, and not to the usual property of real clusters, in which the stars move in space with the same speed in parallel directions. W. M. S.

Double Stars

Measures and New Pairs.—The most important publication on double stars in 1931 was the twelfth series of measures by van den Bos in *Union Observatory Circular* 85. The list consists of 2017 measures of 488 stars, including many very close pairs discovered by van den Bos, Innes and the Lick observers. These measures constitute a very important addition to the measures of southern double stars.

Other series of measures are as follows :—

Observer	Reference	No. of Stars	Notes
Barton, S. G.	*A.J.*, 953	444	Astrographic plates −2° to −10°. 221 in standard catalogues, 213 new, 10 suspected. New stars faint.
Doberck, W.	*A.N.*, **243**, 121	94	Miscellaneous, fairly close.
Espin, T. E. and Milburn, W.	*M.N.*, **91**, 294	44	New, faint mostly under 8″.
		43	,, ,,
Phillips, T. E. R.	*M.N.*, **91**, 238	48	Mostly Σ.
Silbernagel, E.	*A.N.*, **241**, 33	348	Rather wide.

Photographic positions of the components of α Centauri for two epochs are given by H. A. Alden (*A.J.*, 954).

Orbits.—The following table gives the principal elements of new orbits :—

Star	Computers	Reference	*P*	*a*	*e*
			Years	″	
85 Pegasi	J. S. Allen	*Pop. Ast.*, **39**, 145	26·86	0·714	0·272
Σ 1757	C. Luplau-Janssen	*A.N.*, **241**, 61	243·96	1·78	0·47
Σ 1819	...	...	141·65	1·11	0·60
h 3494	W. S. Finsen	*U.C.*, 84	135·1	1·464	0·55
			166·7	1·358	0·39
			191·6	1·365	0·32

With a parallax of 0″·086, Allen finds the combined mass of 85 Pegasi 0·794 times that of the Sun. In agreement with previous results from measures of a faint neighbouring star, but contrary to the general results for double stars, he finds the brighter star the less massive, 0·286 times that of the Sun or only 36 per cent. of the total mass. In *L.O.B.*, 432, L. Berman discusses the spectroscopic orbit of the fainter companion of the well-known binary ξ UMa. The total mass of the four stars is given as 2·27 ; 1·28 being the mass of the principal spectroscopic binary and 0·99 that of the fainter.

An ephemeris of α Centauri is given by Gondolatsch (*A.N.*, **242**, 328). See also *U.C.*, 84, p. 182.

General.—In order to obtain as much information as possible as to the masses and parallaxes of double stars for which the relative motion so far observed is too short for the computation of orbital elements, formulæ have been derived which use statistical values of several unknowns. The fullest study in the past of the statistical quantities has been made by H. N. Russell. During 1931 D. Barbier has published three papers on this question in *Comptes Rendus* (**192**, 1635 ; **193**, 709 ; and **193**, 1393). He points out that in the stars actually observed there is not a uniform distribution of the mean anomaly. When the two stars are closest they may escape separate observation, while when near elongation the motion may be too slow to be detected. In the first paper he gives the provisional percentage distribution as

$\pm g$	0°	30°	60°	90°	120°	150°	180°
	16·9	14·7	12·3	20·4	23·6	12·1	

The distribution of eccentricity he finds as follows :—

e	0	0·3	0·5	0·7	0·9	1·0
	9·2	29·8	23·5	34·4	3·1	

In the second paper for binaries with computed orbits of period exceeding one hundred years, he finds the following distribution of mean anomaly at 1900 :—

$\pm g$	0°	30°	60°	90°	120°	150°	180°
	52·6	7·9	13·1	7·9	10·6	7·9	

This, of course, is what would be expected from the fact that for binaries of long period the calculation of elements is only possible when the observations cover the period of closest approach.

In the third paper M. Barbier returns to the calculation of the mean value of e^2. Discussing it in reference to spectral type he finds the following results:—

Spectral Type	B	A	F	G	K
No. of pairs	8	19	38	29	13
Mean value of e^2	0·323	0·347	0·378	0·430	0·458

M. Barbier also discusses the distribution of the poles of the orbits, in *Comptes Rendus* (**193**, 839), and finds a concentration near $\lambda = 330°$, $\beta = 0°$, not far from the centre of the galaxy at $\lambda = 325°$, $\beta = 0°$. In *Journal des Observateurs* (**14**, 137) M. Barbier finds that there is a slight indication that the values of e and log P increase with galactic latitude for both spectroscopic and visual binaries. J. J.

Mathematical Tables

During the seven years that have elapsed since the last report on this subject appeared in these pages, there has been considerable activity in the field of table-making. The new tables reflect the modern tendency towards

the use of calculating machines in three ways—first, by the extensive use of machines in their making, as reported in prefaces ; secondly, by the fact that logarithmic values are tending to be superseded by natural ; and thirdly, because the possession of a machine is virtually assumed in tables of special functions, where a wide interval is used and several even orders of differences provided. Another outstanding feature of the period is the publication of special tables required in applications of mathematical physics.

Logarithms of Numbers.—Four volumes of Thompson's *Logarithmetica Britannica* have now been issued, containing the logarithms to 20 decimals of the numbers 40,000–60,000 and 80,000–100,000, together with their second and fourth differences. Mr. P. Ramsey-Kent has advertised the original manuscript and copyright of a *Control Tables of Logarithms*, in two foolscap volumes, for £300, but has not published any details of the contents of these volumes. Interest in logarithms is, however, now so much on the wane that it seems doubtful if this table will ever be published. A 5-figure critical table of addition and subtraction logarithms published by Berkeley would have been much more valuable had it been published 50 or 100 years ago ; nevertheless it should appeal to navigators, although, as the author wittily remarks, " The young ones, not the old. To teach old dogs new tricks is proverbially difficult. In the case of old sea dogs, it is hopeless."

A table by Duarte, giving values of log $n!$ to 33 decimals up to $n = 3000$, is by far the most extensive table of this function ever published. Degen's table (Copenhagen, 1824), giving 18 decimals up to $n = 1200$, was recomputed by Peters, and published in his *Zehnstellige Logarithmen* (Berlin, 1922). Six errors in Degen, found by Ramsey-Kent, were published in the B.A. Report for 1926. Degen's values, to 10 decimals, have been published by E. S. Pearson as logarithms of the gamma function.

The unreliability of Steinhauser's 21-figure *Logarithmen* (Vienna, 1880) has been pointed out on various occasions, the largest known contribution to the list of errors having been made by E. B. Escott (*American Mathematical Monthly*, **32**, 418). One per cent. of the values in Table A are in error, mostly by one or two units in the 8th, 9th or 10th decimal.

Duffield's table of 10-figure logarithms of numbers, published as Appendix No. 12 to the U.S. Coast and Geodetic Survey Report for 1896, purported to be an original calculation, but appears actually to be a copy of Vega's *Thesaurus Logarithmorum* (Leipzig, 1794). The resemblance has been pointed out in detail by Peters (*Zehnstellige Logarithmen*), Henderson (*Bibliotheca Tabularum Mathematicarum*, 147) and Comrie (*B.A.A.J.*, **36**, 339).

Natural Trigonometrical Tables.—A second edition of Mrs. Gifford's *Natural Sines* to 8 decimals for every second of arc appeared in 1926. New type was set for this edition, and the author has reverted to modern-face figures, instead of using old-style figures as in the first edition. There have been many lapses in the proof-reading, so that the second edition has more errors than the first. There is a curious tendency (in both editions), especially near 90°, for the 6th decimal to be in error by a unit. The same author's companion volumes of *Natural Tangents* and *Natural Secants* appeared in 1927 and 1929 respectively. These tables have been produced

by interpolating Rheticus (for the sines) and Andoyer (for the tangents and secants) from 10″ to 1″. Examination of the tangents, especially between 60° and 90°, shows that the last figure is unreliable, because insufficient differences were taken into account in the interpolation. In the later degrees a periodic error, with an amplitude up to 3 units of the last decimal, has been introduced by this neglect. Other faults, common to all three volumes, are that the tables have not been arranged semi-quadrantally, successive entries are in rows instead of in columns, while the proportional parts given cannot be used as they do not relate to the actual differences of the tables. Nevertheless one must respect the energy and perseverance required to produce 1800 pages, containing just under 1,000,000 entries.

The need for natural values of the trigonometrical functions for use with calculating machines has stimulated no less than six authors into the making of 7-figure tables for every 10″. The first of these, by C. H. L. Max Jurisch, was first published in South Africa in 1884 ; it is expensive, and has practically no sale outside that country. It contains sines and cosines only, based on Rheticus (1596) and Pitiscus (1613) ; even the fourth edition contains at least six gross errors. Jordan's *Opus Palatinum* (Leipzig, 1897 and 1913) contains the same functions, from the same sources ; one error only is known. The first table containing four functions was Brandenburg's (Leipzig, 1923), based on Rheticus, the author being evidently unaware of the publication by Andoyer in 1915–18 of his *Nouvelles Tables Trigonometriques Fondamentales* (*Valeurs naturelles*) containing accurate 15-figure values of the six functions at interval 10″. Brandenburg provided a supplementary table of cotangents from 0°–6° at interval 1″. The table was badly printed on poor paper, and contained over 400 errors. A new edition, published in 1931, is practically free from error ; it has been produced by a photographic process, and, although the typography is poor, it is the most reliable source at present available for these functions.

The New Zealand Department of Lands and Survey in 1927 printed tables of natural sines and cosines based on Jurisch, for departmental use. In the same year Benson, of Los Angeles, published a table containing the four functions. The preface, most of which is of the nature of a treatise on trigonometry and has no bearing on the tables, makes no mention of the actual source of the tables. A thorough checking of the table revealed 150 errors, which, apart from a few copying or proof-reading errors, can be found in Rheticus, and are also in Brandenburg, who openly stated the source of his values. A similar table was published in 1931 by Ives, of New York, who also does not state his sources, merely stating that "all quantities . . . were checked by fifteen place tables." The 15-place tables are, however, not those of Andoyer as one might imagine, but those of Pitiscus, as is shown by the 50 errors found by comparison with Andoyer. Most of the errors in Ives are also in Benson and the first edition of Brandenburg—all derived from the same source. From internal evidence it is clear that neither Benson nor Ives has printed from plates, thus introducing the grave risks associated with movable type.

Peters has published a 6-figure table of the six functions for every 10″,

while a similar table by Brandenburg with four functions only is in press. The table by Peters is so perfect that the publication of a rival table of the same scope seems unnecessary.

Peters and Comrie are collaborating in the preparation of 7-figure and 8-figure tables for every 1″, produced by interpolating Andoyer. The first two volumes, each of 900 pages, will contain 7-figure and 8-figure values of the four principal functions, arranged semi-quadrantally. The work of making the copy for these is now more than half completed. Comrie has prepared also 7-figure tables for every second of time. These are now being used in manuscript, but it is hoped that they will be published later in better financial times.

Centesimal Division of the Quadrant.—It is to be regretted that recent attempts have been made to revive this division of the quadrant. Had it been adopted at the time of Briggs it would undoubtedly have been the best system, but the nonagesimal degree is now firmly established, and the need for a decimal division is met by decimalising the degree, using such tables as those to 5 figures by Lohse (Leipzig, 1909), or to 7 by Peters (Berlin, 1918). In the centesimal division 5-figure tables have been made available by Steinbrenner (Braunschweig, 1914), 6-figure by Peters and 8-figure by Roussilhe and Brandicourt.

Collected Tables.—A comprehensive collection of tables has been published by Milne-Thomson and Comrie, under the title *Standard Four-Figure Mathematical Tables*. These tables contain logarithms, anti-logarithms, addition and subtraction logarithms, roots, powers, reciprocals, six natural and four logarithmic trigonometrical functions with arguments in degrees and decimals, degrees and minutes, and radians, hyperbolic and exponential functions, natural logarithms, inverse circular and hyperbolic functions, the gudermannian and its inverse, the gamma function and the probability integral, together with derivatives, integrals, series and formulæ. A separately published table by Comrie gives the trigonometrical functions with the argument in time.

Tables of Squares, etc.—Barlow's *Tables of Squares, Cubes, Square Roots, Cube Roots and Reciprocals* have been entirely reset for a new (third) edition, edited by Comrie. Larger and clearer type has been used, a column showing $\sqrt{10n}$ has been added, while differences are given for all roots and reciprocals. Factorials are now included up to $n = 100$, n^4 and $n^{-\frac{1}{2}}$ up to $n = 1000$, powers to the 10th to $n = 100$ and to the 20th to $n = 10$. Milne-Thomson's *Standard Table of Square Roots* gives the material of two columns only of Barlow (and one of these to a figure less).

A volume of *Calculating Tables* by Yano gives products up to 1000×1000 as in Crelle, but omits the pages giving products of multiples of 10. Its smaller size may occasionally render it more convenient than Crelle. A small table by Peters gives proportional parts for all 3-figure numbers.

Circular (argument in radians), Hyperbolic and Exponential Tables.—The Smithsonian tables were reprinted in 1924. Kennelly has published *Tables of Complex Hyperbolic and Circular Functions*, while Pernot and Woods have contributed *Logarithms of Hyperbolic Functions to Twelve Significant*

Figures, with first, second and third differences. It is difficult to imagine that more than 8, or in rare cases 10, figures are ever wanted in these functions. Also natural values are to be preferred, and these are found in Hayashi's *Sieben- und mehrstellige Tafeln der Kreis- und Hyperbelfunktionen*, which gives values, mainly 10-figure but some 7 and 8-figure, of the circular, exponential and hyperbolic functions, with their inverses, at interval 0·001 up to 3·000, and 0·01 from 3·00 to 10·00. This table is completely marred by the largest percentage of gross errors we have found in any modern table. More than 1000 errors have been found in the portions of the table examined ; in fact, one value in every 50 on the average appears to be incorrect. These appear to be not merely rounding-off errors or printer's errors, but definitely calculating blunders, all of which could have been detected had the author differenced his values. The same author's *Fünfstellige Tafeln* also shows evidence of carelessness. A further table, *Fünfstellige Funktionentafeln*, is based on the large volume described above. The checking of the first four pages revealed 13 gross errors, together with 4 errors of a unit in the last decimal due to errors in the 7-figure tables, and 9 more due to inaccurate rounding-off.

The British Association *Mathematical Tables*, vol. i, gives extensive tables of circular and hyperbolic sines and cosines, sine, cosine and exponential integrals, as well as integrals of the probability integral. Sine and cosine integrals are also given in a table by Tani.

Miscellaneous Functions.—The most convenient collection of tables of higher and special functions is that of Jahnke and Emde. The British Association Reports contain various tables, mostly connected with Bessel functions and the confluent hypergeometric function. The Association's *Mathematical Tables*, vol. i, in addition to tables already mentioned, tabulates the factorial (gamma) function and its successive derivatives. Vol. ii, now in the press, contains solutions of Emden's equation and various associated functions. Legendre's table of logarithms of the gamma function from 0 to 1 has been reproduced photographically by Karl Pearson. It has been extended to 50·9 by Brownlee and to 1200 by E. S. Pearson.

Tables of elliptic functions, at intervals that are too wide for most practical purposes, have been given in a volume published by the Smithsonian Institution. Nagaoka and Sakurai have tabulated theta functions and complete elliptic integrals, introducing as argument k^2, where $k = \sin\phi$ and denotes the modulus. In the older tables the argument is ϕ, which is much less convenient. Emde has issued a photographic reprint of Legendre's *Tafeln der elliptischen Normalintegrale* (Paris, 1826), a valuable table that had long been out of print. Milne-Thomson has tabulated, to 5 decimals, the elliptic functions *sn*, *cn* and *dn*.

Extensive tables of Bessel and elliptic functions are given in Hayashi's *Tafeln der Besselschen, Theta- und anderer Funktionen*, and in his smaller *Fünfstellige Funktionentafeln*. Meissel's great table of $\mathcal{J}_0$ and $\mathcal{J}_1$ to 12 decimals at interval 0·01 up to 15·50 has been extended to 25·10, with 22 errors (all in the 9th or earlier decimals) in 1920 values. Other tables examined were found to be equally faulty.

Extensive tables of the incomplete gamma-function, which is used by statisticians, have been edited by Karl Pearson, who has also produced a second volume of his *Tables for Statisticians and Biometricians*, consisting mainly of tables that have appeared from time to time in *Biometrika*. A smaller collection of the tables most frequently used by statisticians is due to Glover. A table of primes and factors, extending to 100,387, has been published by Mrs. Gifford.

Extensive tables of the incomplete B-function have been produced in the Galton Laboratory of University College under the supervision of Karl Pearson. These tables, which are of triple entry and will run to 1000 quarto pages, are now awaiting financial assistance before they can be published.

Interpolation Tables.—A table giving Bessel, Gauss and Everett coefficients at interval 0·001 has been published by Chappell. The Everett coefficients extend to the fourth difference only, so that, if the seventh difference is appreciable, Thompson's *Table of the Coefficients of Everett's Central-Difference Interpolation Formula* must be used. A method of avoiding the tabulation of certain higher order differences is described in the British Association *Mathematical Tables*, vol. i.

Critical Tables.—The advantages of critical tables, when such are applicable, are becoming more widely realised. If $y = f(x)$, an ordinary table tabulates y at equal intervals of x, but a critical table tabulates the ranges of x in which y has values differing by a unit. This results in the elimination of interpolation and in accuracy to within half a unit of the last figure in y, whereas an interpolate from an ordinary table may be a whole unit in error. An article on the subject by Mackerras appeared in *B.A.A.S.*, **42**, 31 (1931).

British Association Tables Committee.—For many years this committee has published tables in its annual reports. Three years ago the committee was reorganised, its first task being the collection into one volume of tables that were scattered throughout various reports. It was found that many of the tables required extension and the addition of even order differences to facilitate interpolation. The committee decided to inaugurate a new series of tables, and in 1931 published its volume i, the contents of which have been mentioned in earlier paragraphs. It is now engaged in preparing a comprehensive and authoritative volume of tables of Bessel functions. The committee has become a clearing-house for tables required in modern mathematical physics, and in this capacity has tabulated solutions of Emden's equation (now in the press), and is tabulating Legendre functions $P_n(x)$ for values of x greater than 1, for use in quantum mechanics.

The committee has recently come into the possession of 30 manuscript volumes containing the calculations of elliptic functions made for the Association under the superintendence of the late J. W. L. Glaisher in 1872–75. These are really the four Jacobian theta functions forming the numerators and the denominator of the elliptic functions *sn*, *cn* and *dn* (inverse to the elliptic integrals). The range covered is $x = 0°, 1° \ldots 90°$, $k = \sin 0°, \sin 1°, \ldots \sin 90°$, and both natural and logarithmic values are given, making altogether 64,800 tabular entries. It is not likely that the

logarithmic values will ever be published ; financial considerations have, so far, prevented publication of the natural values, which would require a volume of 180 pages.

Lieut.-Col. A. J. C. Cunningham, R.E., who died in 1928, left to the committee £3000 "for preparing new mathematical tables in the theory of numbers." A programme of work under this bequest is now being put in hand.

Literature.—The standard sources of information on tables have been the British Association Reports for 1873 and 1875, Glaisher's articles, "Table, Mathematical" and "Logarithm" in the eleventh edition of the *Encyclopædia Britannica*, the *Napier Tercentenary Celebration Handbook* (Edinburgh, 1914) and the reports in these Notices in 1912 and 1925. In 1926 there appeared the first part of the *Bibliotheca Tabularum Mathematicarum*, by J. Henderson, under the editorship of Karl Pearson. This is a detailed description of all tables giving logarithms of numbers to 6 decimals or more, and is invaluable to anyone wishing to acquire an expert knowledge of tables. We look forward to the promised further volumes dealing with trigonometrical tables, etc.

A number of errors in the *Napier Tercentenary Celebration Handbook* and in the *Encyclopædia Britannica* were pointed out by Comrie in *Obs.*, 52, 324 (1929 November). In the fourteenth edition of the *Encyclopædia Britannica* Glaisher's articles have been rewritten by Henderson. A working list of mathematical tables (up to 8-figure), together with the full titles, publishers and prices of the tables mentioned, was given by Comrie in *B.A.A. Handbook for* 1929.

Mechanical Tabulation.—Great advances in table-making have been made by the application of ledger-posting machines to the problem of building up tables from their predetermined differences. This was the method contemplated by Babbage in his unfinished difference engine. A Burroughs Class 11 machine has been used for this purpose for nearly three years in H.M. Nautical Almanac Office ; it integrates from second differences, printing argument, function (up to 13 figures) first and second differences, at the rate of 500 to 600 complete cycles per hour. Other Burroughs machines will integrate from higher order differences, while the Ellis machine (National Cash Register Co.) will integrate from the sixth difference, or difference a given function to the sixth difference, printing all the differences, in 15 seconds per line. A powerful method of interpolating tables to tenths, known as the end-figure method, which utilises the Hollerith tabulating machine to produce the differences required for the integrating machines, has been described in *M.N.*, 88, 506 (1928 April), and *N.A.*, 1931, 828. It is not too much to say that the discovery of the facilities afforded by these commercial machines has revolutionised the art of table-making. For instance, a machine will round-off a function value at any desired point, so that accurate and legible printer's copy may be produced directly.

A non-printing differencing and integrating machine (to and from fourth differences) has been made by A. J. Thompson. The Brunsviga-Dupla (*M.N.*, 88, 447, 1928 March) and Brunsviga IVa (*M.N.*, 91, 819, 1931

May), although non-printing machines, will integrate from second differences ; the former will also difference a function directly to its second difference.

Printing Technique.—The standard of table printing, especially in this country, has risen considerably, and there is evidence that authors and publishers are giving more attention to typographical detail. There is now much more general recognition of the superiority of old style (head and tail) figures, with sufficient space between lines to prevent ascenders and descenders from coming into contact. Another point of the utmost importance is that tables should be printed from stereo or electro plates, and not from movable type. Examples of good English printing are Thompson's *Logarithmetica Britannica* (Cambridge University Press), the *Standard Four-Figure Mathematical Tables* (Glasgow University Press) and the British Association *Mathematical Tables* (Neill & Co.). German printing is usually high-class, but American printers almost invariably use modern-face (equal height) figures.

No satisfactory method of type-setting from a calculating machine has yet been found. Some attempts have been made to produce plates photographically from figures printed by an adding machine, but the results are unsatisfactory, not because of photographic difficulties, but because of the difficulty in preparing the copy so that it resembles type printing.

The new tables mentioned in this report are :—

Barlow's *Tables of Squares, Cubes, Square Roots, Cube Roots and Reciprocals of all Integer Numbers up to* 10,000. Third edition, edited by L. J. Comrie. London, Spon, 1930. $5\frac{1}{2} \times 8\frac{1}{2}$, cloth. Pp. xii + 208 ; price 7s. 6d.

Benson, R. E. *Natural Trigonometric Functions.* Los Angeles, Benson Book Co. ; second edition, 1929. $6 \times 9\frac{1}{2}$, cloth. Pp. 180 ; price $6.00.

Berkeley, L. M. *Addition-Subtraction Logarithms to Five Decimal Places.* New York, White Book and Supply Co., 1930. $7 \times 9\frac{1}{2}$, paper. Pp. xii + 135 ; price $3.25.

Brandenburg, H. *Siebenstellige trigonometrische Tafel für Berechnungen mit der Rechenmaschine.* Second edition. Leipzig, Alfred Lorentz, 1931. 8×11, cloth. Pp. xxiv + 340 ; price 36 marks.

British Association for the Advancement of Science. *Mathematical Tables, Volume I.* London, British Association, 1931. $8\frac{1}{2} \times 11$, cloth. Pp. xxxv + 72 ; price 10s.

Brownlee, J. *Log* $\Gamma(x)$ *from* $x = 1$ *to* 50·9 *by Intervals of* ·01. London, Cambridge University Press, 1923. 6×9, paper. Pp. 23 ; price 3s. 9d.

Chappell, E. *A Table of Coefficients to Facilitate Interpolation by means of the Formulæ of Gauss, Bessel and Everett.* London, published by the author, 1929. 9×11, cloth. Pp. 27 ; price 4s. 6d.

Comrie, L. J. *Four-Figure Tables of the Natural and Logarithmic Trigonometrical Functions with the Argument in Time.* London, published by the author, 1931. $7\frac{1}{2} \times 10\frac{1}{2}$, paper. Pp. 32 ; price 4s.

Duarte, F. J. *Nouvelles Tables de log n! à 33 decimales, depuis* $n = 1$ *jusqu'à* $n = 3000$. Paris, Index Generalis, 1927. $6\frac{1}{2} \times 9\frac{1}{2}$, paper. Pp. xxiv + 136.

Gifford, E. *Natural Sines to every Second of Arc and Eight Places of Decimals,* second edition, 1926 ; also *Natural Tangents, etc.,* 1927, and *Natural Secants, etc.,* 1929. Manchester, Heywood. $6\frac{1}{2} \times 9\frac{1}{2}$, cloth. Pp. 540, 620, 562 ; price 35s. each.

Gifford, E. *Primes and Factors.* Manchester, Heywood, 1931. $6 \times 9\frac{1}{2}$, cloth. Pp. 94 ; price 7s. 6d.

Glover, J. W. *Tables of Applied Mathematics in Statistics. Part III, Probability and Statistical Functions.* Ann Arbor, Wahr, 1924. 6 × 9, cloth. Pp. 100; price $1.50.

Hayashi, K. *Sieben- und mehrstellige Tafeln der Kreis- und Hyperbelfunktionen und deren Produkte sowie der Gamma-funktion.* Berlin, Springer, 1926. 8½ × 11, cloth (also in paper). Pp. vi + 283; price, bound, 48 marks.

Hayashi, K. *Fünfstellige Funktionentafeln.* Berlin, Springer, 1930. 6½ × 10, cloth (also in paper). Pp. viii + 126; price, bound, 30 marks.

Hayashi, K. *Fünfstellige Tafeln der Kreis- und Hyperbelfunktionen sowie der Funktionen e^x und e^{-x} mit den natürlichen Zahlen als Argument.* Berlin and Leipzig, de Gruyter, 1928. 6½ × 9½, paper. Pp. 182; price 9 marks.

Hayashi, K. *Tafeln der Besselschen, Theta-, Kugel- und anderer Funktionen.* Berlin, Springer, 1930. 8½ × 11, cloth. Pp. v + 125; price 26 marks.

Henderson, J. *Bibliotheca Tabularum Mathematicarum, being a Descriptive Catalogue of Mathematical Tables.* Part I, Logarithmic Tables. (A. Logarithms of Numbers.) London, Cambridge University Press, 1926. 6½ × 9, paper. Pp. iv + 208; price 9s.

Ives, H. C. *Natural Trigonometrical Functions to Seven Decimal Places for Every Ten Seconds of Arc.* New York, Wiley; London, Chapman & Hall, 1931. 7 × 10, cloth. Pp. 329; price 56s.

Jahnke, E., and Emde, F. *Funktionentafeln mit Formeln und Kurven.* Second edition. Leipzig and Berlin, Teubner, 1923. 6 × 9, paper. Pp. xii + 176; price 8 marks.

Kennelly, A. E. *Tables of Complex Hyperbolic and Circular Functions.* Cambridge, U.S.A., Harvard University Press; second edition, 1921. 7 × 10, cloth. Pp. 240.

Legendre, A. M. *Tafeln der elliptischen Normalintegrale erster und zweiter Gattung.* Herausgegeben von Fritz Emde. Stuttgart, Wittwer, 1931. 6½ × 9, cloth. Pp. 81; price 3.50 marks.

Milne-Thomson, L. M., and Comrie, L. J. *Standard Four-Figure Mathematical Tables.* London, Macmillan, 1931. Edition A, with positive characteristics in the logarithms; Edition B, with negative characteristics in the logarithms. 7½ × 11, cloth. Pp. xvi + 245; price 10s. 6d.

Milne-Thomson, L. M. *Standard Table of Square Roots.* London, Bell, 1929. 6 × 10, cloth. Pp. x + 100; price 7s. 6d.

Milne-Thomson, L. M. *Die elliptischen Funktionen von Jacobi.* Berlin, Springer, 1931. 5½ × 8, cloth. Pp. 69; price 10.50 marks.

Nagaoka, H., and Sakurai, S. *Tables of Theta-Functions, Elliptic Integrals K and E, and Associated Coefficients in the Numerical Calculation of Elliptic Functions.* Scientific Papers of the Institute of Physical and Chemical Research, Table No. 1. Tokyo, Komagone, Hongo, 1922. 7½ × 10, paper. Pp. 67; price 3 yen.

N.Z. Department of Lands and Survey. *Natural Sines and Cosines for every Ten Seconds of Arc and to Seven Places of Decimals.* Wellington, Government Printer, 1927. 8 × 13, cloth. Pp. 99; price 22s. 6d.

Pearson, E. S. *Table of the Logarithms of the Complete* Γ*-Function for Arguments 2 to 1200, i.e. beyond Legendre's Range.* London, Cambridge University Press, 1922. 6 × 9, paper. Pp. x + 16; price 3s. 9d.

Pearson, K. (edited by). *Tables of the Incomplete* Γ*-Function.* London, H.M. Stationery Office, 1922. 8½ × 11, boards. Pp. xxxi + 164; price 42s.

Pearson, K. (edited by). *Tables for Statisticians and Biometricians, Part II.* London, Biometric Laboratory, University College, 1931. 8½ × 11, cloth. Pp. ccl + 262; price 30s.

Pearson, K. (edited by). *Tables of the Logarithms of the Complete* Γ*-function to Twelve Figures*, originally computed by A. M. Legendre. London, Cambridge University Press, 1921. 8 × 10, paper. Pp. iv + 10; price 3s. 9d.

Pernot, F. E., and Woods, B. M. *Logarithms of Hyperbolic Functions to Twelve*

Significant Figures. In University of California Publications in Engineering, Vol. I, No. 13. Berkeley, University of California Press, 1918. 7 × 10½, paper. Pp. 171.

Peters, J. *Sechsstellige Tafel der trigonometrischen Funktionen, enthaltend die Werte der sechs trigonometrischen Funktionen von zehn zu zehn Bogensekunden des in 90° geteilten Quadranten und die Werte der Kotangente und Kosekante für jede Bogensekunde von 0° 0′ bis 1° 20′.* Berlin, Dümmler, 1929. 7 × 10, cloth (also in paper). Pp. viii + 293; price, bound, 52 marks.

Peters, J. *Sechsstellige trigonometrische Tafel für neue Teilung.* Berlin, Wichmann, 1930. 7 × 10, cloth. Pp. 170; price 18 marks.

Peters, J. *Multiplikations- und Interpolationstafeln für alle ein- bis dreistelligen Zahlen.* Berlin, Wichmann, 1930. 6½ × 10, stiff paper. Pp. 23; price 1.75 marks.

Roussilhe and Brandicourt. *Tables à 8 Décimales des valeurs naturelles des sinus, cosinus et tangentes dans le système décimal, de centigrade en centigrade.* Section de Géodésie de l'Union Géodésique et Géophysique Internationale. Publication Spéciale No. 1. Paris, Dorel, 1925. 7 × 10½, cloth. Pp. 139; price 60 francs.

Smithsonian Mathematical Tables. Hyperbolic Functions. Prepared by G. F. Becker and C. E. van Orstrand. Washington, Smithsonian Institution, third reprint, 1924. 6 × 9, cloth. Pp. li + 321; price 15s.

Smithsonian Mathematical Formulæ and Tables of Elliptic Functions. Washington, Smithsonian Institution, 1922. 6 × 9, cloth. Pp. 314; price 15s.

Tani, K. *Tables of si(x) and ci(x) for the Range x = 0 to x = 50.* Meguro, Tokyo, Naval Experimental and Research Establishment, 1931.

Thompson, A. J. *Table of the Coefficients of Everett's Central-Difference Interpolation Formula.* London, Cambridge University Press, 1921. 6 × 9, paper. Pp. xvi + 20; price 3s. 9d.

Thompson, A. J. *Logarithmetica Britannica, being a Standard Table of Logarithms to Twenty Decimal Places.* Part IX, 90,000–100,000, 1924; Part VIII, 80,000–90,000, 1927; Part IV, 40,000–50,000, 1928; Part V, 50,000–60,000, 1931. London, Cambridge University Press. 8½ × 11, paper. Pp. 100 each; price 15s. each.

Yano, Tsuneta. *Calculating Tables.* Tokio, First Mutual Life Insurance Company of Japan. 8 × 5, cloth. Pp. 1816; price 16s. L. J. C.

The Distances and Spectrum Line Displacements of the Extra-Galactic Nebulæ

In view of the recent work of De Sitter and Eddington on the expansion of the universe, and the far-reaching suggestions and conclusions which have been drawn with regard to both its past and its future, it is perhaps desirable to turn our attention again to the observational and physical evidence on which this theoretical structure has been erected.

The early pioneer work of V. M. Slipher at the Lowell Observatory gave conclusive evidence that very considerable shifts in the positions of the H and K lines were to be found in spectra of extra-galactic nebulæ. A small group of these in the same region of the south galactic hemisphere (M31, 32, 33 and N.G.C. 6822) give shifts towards the blue corresponding to negative velocities from 70 to 300 km./sec., but with these few exceptions both spiral and elliptical nebulæ consistently show large displacements towards the red. In 1929, Hubble took up the question and in a valuable and suggestive paper (*Mt. Wilson Communications*, No. 105; *Proceedings of the Nat. Acad. of Sciences*, **15**, 168) showed that a relationship existed between the amount of this line-shift and a probable scale of distances of

the extra-galactic nebulæ. This scale of distances was derived first of all from various types of stars involved in the Andromeda nebula and M33. This has now been extended both nearer and farther by including the Greater and Lesser Magellanic Clouds (which are regarded as irregular extra-galactic nebulæ) and other objects.

In a paper on "The Velocity-Distance Relation among Extra-Galactic Nebulæ" (*Mt. Wilson Cont.*, 427; *Ap. J.*, 74, 43 (1931)) Hubble and Humason give a list of the nearest eight objects, the distances being derived from the absolute magnitudes of involved stars, which include novæ, Cepheid variables, irregular variables, and stars of the P Cygni, Bo and O types (sometimes in connection with emission nebulosity). These distances are expressed in a unit defined by the zero-point of the period-luminosity relation amongst Cepheids: Shapley's recent revision of this unit reduces the previously current value by 11 per cent., and therefore reduces the estimated distances by this amount, without altering the relative scale.

The estimated distances of these eight objects are given below :—

System	Distance in Parsecs $\times 10^5$
Large Magellanic Cloud	0·262
Small Magellanic Cloud	0·290
N.G.C. 6822	1·92
M33	2·36
M31	2·47
M101	4·0
N.G.C. 2403	(6·3)
M81	(7·3)

The distances of N.G.C. 2403 and M81 are suggested by a comparison of 5 irregular variables in the former and 7 in the latter, with stars of the same type in M31 and M33, and are not based on Cepheids. The position of N.G.C. 6822 as third on the list, nearer than M33 and the Andromeda nebula, is not surprising, as it is a large irregular nebula having much the same characteristics as the Magellanic Clouds (vide *Mt. Wilson Cont.*, 304; *Ap. J.*, **62**, 409 (1925)).

As stars are as yet not available as a criterion of distance except in the nearer examples, for statistical purposes some other criterion of distance had to be adopted. The most obvious is the apparent diameter, which must vary on the average in inverse ratio to the distance for any particular type. Hubble and Humason prefer to adopt total luminosity, on the ground that, while increased exposure systematically extends the linear dimensions on the plate up to a superior limit, the percentage of increased diameter is much greater than the percentage of total luminosity, as there is normally a great concentration of luminosity in the nuclear regions. In support of this they say: "It frequently happens that moderate exposures on faint nebulæ register diameters only one-third those which full exposures reveal, while two-thirds of the total luminosities are registered." Once again the importance of a photographic scale of standardised integrated luminosities is thus emphasised. The visual scale of comparative total luminosities with

out-of-focus stars, compiled by Holetschek and revised by Hopmann, although a uniform scale, can only be regarded as elementary and provisional.

For a photographic scale of integrated magnitudes Hubble and Humason have used with advantage out-of-focus nebular images with a 10-inch Cooke lens, compared with out-of-focus images of stars of known magnitudes on the international scale. Similar work has been done by Shapley (*Harvard Circular*, No. 294), and a comparison between them shows differences as great as 3 magnitudes, which is hardly satisfactory. The importance of all this is evident when it is realised that the ultimate value of the velocity-distance unit derived by Hubble, and adopted in the theoretical work of De Sitter and Eddington, is dependent on determinations of distances. These in turn cannot be made satisfactorily until more consistent results are derived for integrated luminosities.

It seems to the writer that, for the smaller nebulæ, reflectors are unsuitable instruments for this work, and that a lens of large diameter and short focus, giving good definition over a large field, is necessary, using out-of-focus images of both nebulæ and stars, as Hubble has already done to a limited extent. For the larger nebulæ, over 5′ in diameter, the total magnitude would preferably be obtained by integrating contours of luminosity in focal images, or perhaps in out-of-focus images.

The relation between estimated distances and apparent radial velocities found by Hubble in 1929 was a linear increase of velocity of about 500 km./sec. per million parsecs. With the revised scale of nebular absolute magnitudes this scale should be increased to 550 km./sec. Hubble and Humason have now extended the work (*Mt. Wilson Cont.*, Nos. 426 and 427 ; *Ap. J.*, **74**, 35, 43 (1931)), especially with regard to certain well-defined groups of elliptical nebulæ. Nebulæ of actual spiral form in these groups are rare.

About 40 new apparent velocities are now available, mostly of small, faint, and presumably distant nebulæ.

Spectrograms were obtained of the brightest objects in eight nebular groups or clusters, of which the Virgo concentration was considered to be one. These gave fairly consistent results except in the case of the Virgo group, which perhaps should be regarded as a concentration in the line of sight rather than a group, as it is a continuation of the great band of nebulæ which stretches from Ursa Major beyond the north galactic pole. In these groups the smallest velocity was found in the Virgo region—580 km./sec.—and the greatest in the faint cluster in Leo discovered by W. H. Christie in 1929, in which a small scale spectrogram of 875 A. per millimetre gave an apparent velocity of 19,600 km./sec.

The integrated nebular magnitudes in these clusters have a large range. For example, in the Coma cluster the values extend from 15 to 19 mag. with a mean of 17 mag. In this cluster, spectra of four nebulæ are available, the mean displacement in three of them being equivalent to 7500 km./sec., with a range of 1200 km./sec. The fourth (N.G.C. 4865) gives 5100 km./sec. It appears to be one of the brightest of the group, and it is suggested that it does not belong truly to the cluster, but is a "field" nebula superimposed on it.

In addition to the group nebulæ, 15 isolated nebulæ are included in the list, of both elliptical and spiral types, the diameters ranging from 0′·3 to 4′·0. The displacement in these ranged from 650 km./sec. in the case of the largest (N.G.C. 4051) to 5100 km./sec. in N.G.C. 6710 (0′·8), both showing spiral structure.

The authors point out that if nebular luminosity approximates to black-body radiation, the red shifts involve a shift of the maximum spectrum energy also, corresponding to lower temperatures and later spectral types. This has a corresponding effect on the photographic magnitudes. For the very distant objects giving the greatest red shifts a correction for magnitude should be applied, which in the case of the Leo cluster was computed to be 0·25 mag. and for the Coma cluster 0·10 mag. For nearer objects the corrections would be less than the uncertainties of magnitude and may be ignored.

Although uncertainties and discrepancies must necessarily occur in such an investigation, owing mainly to the heterogeneous nature of the observational material, the results seem to show that the relation between distance and apparent velocity shift found in 1929 can now be carried a good deal further, with a revised and rounded figure of 560 km./sec. per million parsecs. The authors believe that the constancy of their magnitude scale is well established, and that apparent magnitudes may be accepted as measures of distance for the various types. At the same time, with commendable caution, they say: "The interpretation of red shifts as actual velocities, however, does not command the same confidence, and the term 'velocity' is used in the sense of 'apparent velocity,' without prejudice to its ultimate significance."

A certain amount of scepticism as to the interpretation of the shifts towards the red as actual velocities is evident amongst physicists, and, as an example of this, a letter to *Nature* of 1932 January 16 may be quoted. In this letter Professor W. D. MacMillan puts forward an alternative view that the red shift is due to loss of energy in the photon in the course of time, due either to an inherent instability of the photon, or possibly to collisions with other photons. In such a case, loss of energy would be equivalent to a decline of frequency. MacMillan calculates, on the hypothesis of energy leakage and the observed shift of the spectrum lines with Hubble's adopted distances, that a light quantum loses 1 per cent. of its energy in 5,400,000 parsecs. He says, "Such an interpretation of the extraordinary shifts that are observed will be more acceptable to many than an interpretation which makes our Galaxy a centre from which all others are fleeing with speeds proportional to the distances."

The usual explanation of the existence of negative velocities in certain of the nearer extra-galactic nebulæ is that the rotation of the galaxy more than counteracts the actual positive velocities.

These negative velocities, with one exception, lie in the south galactic hemisphere between λ 80° and 110° and β 20° and 35°. If, therefore, we can find two nebulæ lying about 180° apart in longitude, and of approximately equal and opposite latitudes, one of which shows a negative velocity,

the other should show a velocity larger than its distance effect by the term introduced by the galactic rotation. Such a pair exists in N.G.C. 598 (M33), λ 100°, β −31°, and N.G.C. 5236, λ 280°, β +31°.

The distance of N.G.C. 598 * is given by Hubble (*Mt. Wilson Communications*, No. 105) as $0{\cdot}263 \times 10^6$ parsecs, and that of N.G.C. 5236 as $0{\cdot}9 \times 10^6$ parsecs. Both distances have been derived from photographic magnitudes of stars involved. The apparent velocity of N.G.C. 598 is −70 km./sec., and as its hypothetical velocity should be +147 km./sec., the galactic rotation effect on this assumption, supposing the nebula has no motion peculiar to itself, would be −217 km./sec. In the case of N.G.C. 5236 the apparent velocity is +500 km./sec., which is practically the value of its hypothetical velocity without having regard to the galactic rotation term. If this were added, its value should be over +700 km./sec. This example shows that the outstanding residuals in the nearer objects are considerable. J. H. R.

* In *Mt. Wilson Communications*, No. 105, the distance is given as $0{\cdot}263 \times 10^6$ parsecs, but in *Mt. Wilson Cont.*, No. 427, this appears as $2{\cdot}36 \times 10^5$.

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Prague, Institut astronomique de l'Université Charles
Radcliffe College, Harvard University
Rome, Reale Accademia d'Italia
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Rome, Società Italiana per il Progresso delle Scienze
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ADDRESS

Delivered by the President, Dr. H. Knox-Shaw, on the award of the Gold Medal of the Society to Dr. Robert Grant Aitken for his work on Double Stars.

It will be recalled by those well versed in the history of the Society that in the early days of its existence Gold Medals were bestowed with a very lavish hand. Thus we find, on referring to the records, that in the year 1826 the Medal was awarded to no less than three persons, Mr. John Herschel, Mr. James South and Professor Wilhelm Struve, for their observations of double stars. Since that time it has been given for work in the same field of astronomy on several occasions, the last of which was in 1894 when Professor Burnham was the recipient. As this date nearly coincides with that on which the Medallist of this year commenced his long series of double-star measurements, it will be of interest to consider in a brief manner the state of our knowledge of the subject at that time.

The first act in the drama of double-star discovery had ended with the publication in 1850 of the Pulkowa Catalogue containing the measures of the Otto Struve stars. It seems to have been thought then that the Herschels and the Struves had made such a clean sweep of the northern sky that the search for new binaries was at an end. For the next quarter of a century observers concentrated on the remeasurement of known pairs, and the new binaries found were incidental to that work. When the curtain rises again, it is upon Burnham in 1870 commencing work with his beautiful 6-inch refractor by Alvan Clark. He soon showed that there were still new double stars to be found even with an instrument of these modest dimensions. In the next twenty-five years he had the opportunity of using several of the world's largest refractors, and by the time he received the Medal the number of his discoveries had risen to over 1200. A year later Robert Grant Aitken made his entry on the stage, in the part of an assistant at the Lick Observatory. The interest of double-star work had by then long shifted from the evidence these bodies afforded on the universality of the law of gravitation, in which it had centred in the time of Sir William Herschel. It then lay in the determination of their frequency, their distribution in the sky, the relation between the magnitudes of the components and their separation, and in the calculation of orbits for such of them as had been observed over sufficiently long arcs. At that time there were only a few such, for the quick-moving doubles are in general the close ones, and the binaries then known with very small separation had been discovered too recently to have shown more than quite small changes in position angle. All these particulars were being sought after as likely to throw light on the origin of binary systems, but perhaps the most valuable information that double stars can give us is knowledge of stellar masses. They afford our only direct means

of attack on this important problem, and even if the method now used for determining spectroscopic parallaxes should be developed so as to give us the star's mass in place of its luminosity, it will still be necessary to calibrate it by reference to the fundamental determination afforded by the double stars, in the same kind of way that spectroscopic parallaxes are dependent on those found trigonometrically. The mass of a binary system is only determinate when its distance is known, and as the function provided by the orbital elements is the product of the mass and the *cube* of the parallax, the latter has to be known with a high degree of accuracy to avoid large errors in the derived mass. This fact provides a second reason why at the close of the last century there were very few systems for which reliable masses had been determined.

Such in brief outline was the extent to which knowledge of this branch of astronomy had progressed when our Medallist, at the outset of his career, turned his attention to it. Burnham's work had shown that there were still double stars to be discovered, but no one since Otto Struve had made a systematic search for them. Mr. Aitken, impressed with the importance of having a mass of homogeneous material that could be used for statistical purposes, embarked in collaboration with Mr. Hussey, who had also recently joined the staff of the Lick Observatory, on a survey of all that part of the heavens that they could reach. They divided the sky from the North Pole to 22° south declination between them, and decided to examine all stars down to magnitude 9·0 on the B.D. scale. At first the search was usually made with the 12-inch refractor, but the duplicity of all discoveries was afterwards checked with the 36-inch, and later on the search and the measures were made entirely with the great telescope. When Hussey left the Lick Observatory in 1905, Aitken took over the whole of the work. Considerable difficulty was experienced with the low stars of the winter sky, and these were excluded from the survey. By the year 1915 the search was finished down to 14° south declination for all right ascensions and to 22° for the twelve hours that came up for observation in the summer months. Subsequently, by agreement with the South African observers, the survey was made complete down to 18° south declination. The measures of stars so discovered by our Medallist have been published in a number of lists, all of which except the first two have appeared in the *Lick Observatory Bulletins*. In the twenty-fifth of these lists, which came out early in 1927, we were told that there remained only 400 stars to be examined. Soon afterwards this had been accomplished, and the final list of 18 discoveries brought the number of Aitken stars to the magnificent total of 3103. Hussey's contribution to the survey had amounted to 1327, so that between them the two observers had added no less than 4430 to the number of known visual binary systems. This number, large in itself, is made relatively greater in comparison with the discoveries of early observers by the fact that throughout the survey an upper limit for distance of 5″ had been fixed. No stars were included with greater separation than this ; for more than half of the new binaries the separation was less than 1″, and for some hundreds of them it was below 0″·25. It is a remarkable tribute to the

observers' skill that a pair with equal magnitudes and separation as low as 0″·25 was almost certain of detection with the 12-inch, and when the 36-inch was being used even those down to 0″·15 did not escape. It is the large proportion of close doubles among the Aitken stars that gives them their great importance, for it is only such stars that can be expected to show orbital motion rapid enough to provide us with information about their masses in a reasonably short space of time. It seems indeed probable that in a few decades there will be as many visual binaries with known orbits among the Aitken stars as among all those discovered before his day.

Some details of our Medallist's methods of observing may be of interest. He found that he could examine for duplicity 200 to 250 stars on a good night, and that on Mount Hamilton there were about 150 nights in the year when the seeing was sufficiently good for work of this kind. Measurement was naturally a slower process, but the routine of making four settings in position angle and three measures of distance, in addition to incidental notes on the magnitudes of the components, the time of the observation, the atmospheric seeing and several other details, could be completed in less than ten minutes ; and the normal rate of measurement under good conditions was five pairs an hour. When observing with the 36-inch—that masterpiece of Alvan Clark and the firm of Warner & Swasey, the erection of which would have been amply justified by its contribution to double-star astronomy alone—he used a power of 520 in the case of the wider doubles, but for those with separations under 1″, powers of 1000 and 1500 were generally employed, and for very close pairs even one of 3000. Dr. Aitken's observing has been characterised by strict adherence to a systematic plan and by a high standard of accuracy, as is shown by the small accidental errors of his measures of even the most difficult pairs.

Before the survey began, and later on as opportunity offered, our Medallist made a considerable number of measures of known binaries. Volume xii of the *Publications of the Lick Observatory* contains the measures of some 1200 of these, largely Burnham and Struve stars, made by him in the first seventeen years of his work on Mount Hamilton. There are also included in the same volume a useful discussion of the errors of his measurements, both accidental and systematic, and new orbits for twenty-six of the stars. It was a definite part of his observing programme to remeasure each of his own stars, after suitable intervals, at two other epochs besides that of discovery, and in 1929 he published his measures of 296 of the Aitken stars in which motion was already apparent. These are naturally almost all very close doubles ; in fact, in 100 of them the maximum separation is less than 0″·25.

Dr. Aitken has computed the orbits of a large number of visual binaries, including some of his own stars, and the results will be found not only in the *Lick Observatory Bulletins* but scattered throughout the pages of the *Publications of the Astronomical Society of the Pacific*, where also from time to time short notes have appeared on the more interesting of his measures. Thus in 1898 he observed the companion of Sirius for the first time on its reappearance after being lost in the rays of its brilliant primary. And in

1923, on hearing from Dr. Joy at Mount Wilson that a displacement of the spectrum of o Ceti at minimum suggested to him that the star must be a binary, Aitken turned the 36-inch on to it and saw, and was able to measure, the companion. What puzzled him was the fact that it had not been seen before, for the separation was nearly 1″ and the companion was only three-quarters of a magnitude fainter than the primary at minimum. He suspected that the companion must itself be variable, and this supposition was strengthened by his observations in subsequent years.

Dr. Aitken quite early laid stress on the futility of attempting to compute orbits from short arcs. Seldom, in his opinion, can a reliable orbit be calculated when the observed arc is less than 180°, and for most double stars about three-quarters of a revolution should have elapsed. At the present time the number of really well-determined orbits is only about one hundred. Among the stars for which our Medallist has published elements is ε Hydræ, which is one of those rare phenomena, both a visual and a spectroscopic binary. He computed orbits from both the micrometer measures and the radial velocities, and with an assumed value of the mass-ratio was able to determine all the particulars of the system. By 1913 the star Aitken 88, discovered in 1901, had completed a whole revolution, and he was able to produce what may aptly be called a " one man orbit," for no one else had observed this difficult star, and the orbit had thus to depend entirely on his own measures. The distance between the components was never greater than 0″·17 and fell as low as 0″·07, so it will readily be understood that even with the 36-inch it was a matter of no small difficulty to make measures that would give a satisfactory orbit. Another star for which Aitken determined an orbit is Krüger 60, one of our nearest neighbours in space. This binary is of special interest because of the low luminosity of its components, both of which are dwarfs of class M, and because of its well-determined parallax, which enables the mass of the system to be fixed with a high degree of accuracy. Thanks to a series of photographic measurements by Alden of the motions of the components with respect to surrounding stars, the mass-ratio was also known, and the individual masses were thus determinate and found to be one-fourth and one-fifth that of the Sun.

The data afforded by the Lick Observatory survey have been utilised by our Medallist for a statistical study of the visual binary stars. It embraces their frequency and distribution in the sky ; a discussion as to how far these vary with magnitude and separation ; the distribution of the binaries among the spectral classes ; the relations between magnitude and separation and of each of these with spectral class ; and the connection between spectral class and galactic latitude. Many of the results do not lend themselves to presentation in an address of this nature, but I will refer to a few of them. It appears that at least one star in eighteen of those brighter than 9·0 on the B.D. scale is capable of being resolved as a double in the 36-inch refractor, and about 4 per cent. of these are multiple systems. The frequency of doubles is slightly higher for low galactic latitudes. Pairs with small orbital dimensions are more common than those with large

separation. There is some evidence that the stars of high luminosity, and consequently of large mass, are more likely to be double than their smaller brethren. The spectral classes most common among visual binaries are those between Ao and Ko, as compared with spectroscopic binaries which favour the classes Bo to Ao.

The foregoing conclusions are all immediately deducible from the observations. Some others depending on knowledge of the orbital motions of the systems, to which our Medallist has either himself drawn attention or towards which his observations have made a valuable contribution, may be mentioned. The orbits of visual double stars so far calculated are in size of the same order as those of the outer planets of our system, but they are much more eccentric, more so indeed than those of the spectroscopic binaries. The latter have eccentricities which average about 0·2, while the mean value for the visual binaries is of the order of 0·5. In fact there is a definite correlation between eccentricity and size of orbit, for in each class of binary the greater the separation the more elongated the orbit. There are, however, exceptions ; some visual double stars with relatively short periods move in highly eccentric ellipses. Such a one is OΣ 341, for which Aitken found a period of only 20 years, but an eccentricity as great as 0·96. The high eccentricity of the orbits of visual double stars is an important observational fact that has to be accounted for by any theory of their evolution. As Jeans has shown, it cannot be explained by tidal effects after fission from a single mass. It has been necessary to postulate perturbations of the orbit by repeated encounters with other stars.

In view of the paucity of visual double stars for which it has yet been found possible to calculate complete orbits, it is fortunate, as was pointed out by Russell and Hertzsprung some years ago, that from a knowledge of the rates of change in position angle and distance, values can be found for the mass-parallax relation that are statistically correct. Owing to the relatively small dispersion in mass as compared with luminosity, it is possible with assumed mean values of the mass to derive parallaxes which, although not accurate, individually prove useful when dealing with classes of stars. Our Medallist utilised this method in connection with 393 of the Aitken stars which by 1926 had shown sufficient orbital motion. He assumed masses of 1·7 ⊙ and 8·8 ⊙ for the systems, according as they were formed of dwarfs or giants, and employing the formula derived by Jackson and Furner for the parallax, he deduced that the average absolute magnitude of the 154 giant systems among these stars was +0·8 and that of the 239 dwarf systems +4·6.

In 1911 Dr. Aitken, impressed with the necessity of doing something to free the family of double stars from the incubus of the large number of wide pairs, which were not only to be found in the older catalogues but were still being observed, launched his working definition of a double star. This was based on the principle of graded limits which Innes had introduced in his *Reference Catalogue of Southern Double Stars*, although the actual limits suggested were different. It is unnecessary for me to describe the definition in any detailed way. It will be sufficient to say that while it was

recognised that it was impossible to devise a rule of this kind that would not exclude some true physical systems, the limits were framed so as to embrace most of the pairs that were likely to be of interest ; and special provision was made that any pairs with proved orbital motion, common proper motion or large parallax should not be excluded from membership of the family merely because their apparent relationship was more distant than the definition held to be proper. The proposal was submitted to all the chief double-star observers, some twenty in number, and although there was a distinct divergence of opinion not only as to the limits suggested but even as to the principle of limitation, a majority expressed themselves in favour of the adoption of the definition.

Recently Dr. Aitken has completed the preparation of a new general catalogue of double stars. It has been based on a card catalogue in which he has for many years kept record of all published observations. It is strictly confined to stars within 120° of the North Pole and to those whose separation is limited by the following formula connecting the distance with the combined magnitude of the components :—

$$\log r = 2{\cdot}8 - 0{\cdot}2 \log m.$$

The limits given by this formula are distinctly wider than those suggested by Aitken in 1911 ; for instance, for a magnitude of 9·0 the formula gives a distance of 10″, whereas the limit set for this magnitude by the definition of 1911 was 3″. These more generous limits are clearly justified by the fact that the new catalogue, which its compiler has suggested should be referred to as the A.D.S., is to some extent based on Burnham's Catalogue, the β.G.C., in which no definite limit was set. As it is, the formula disqualifies some 30 per cent. of the stars in the β.G.C. from being considered as binaries. And so, although the A.D.S. has only some 3500 more entries than its prototype, nearly half of its 17,180 stars have been discovered since the date of the β.G.C. The new catalogue, which will doubtless take the place of Burnham's great work as the standard book of reference for that part of the sky with which it deals, is now in the press, and its publication is eagerly awaited by all students of double stars.

By no means the least of our Medallist's contributions to his chosen branch of astronomy is a text-book which appeared in 1918 entitled *The Binary Stars*. This work gives a comprehensive and authoritative account of every phase of the subject, treating of spectroscopic as well as visual binaries. It has proved invaluable to double-star workers, being well furnished with references and containing, besides a history of the subject, much sound advice as to methods of observation and on the computation of orbits. If I may be allowed to quote a passage from this book, I will choose one that strikes me as being typical of the author, as a man content with nothing but the best : " The most important precaution to be taken in double-star observing is quite independent of instrumental adjustments. It is *to make measures only on nights when the observing conditions are good.* Measures made under poor observing conditions are at best of little value, and at worst are a positive hindrance to the student of double-star motions.

They annoy or mislead him in his preliminary investigations and are practically rejected in his later work. I make this statement with all possible emphasis." The book closes with a statistical study of the double stars in the northern hemisphere, some of the conclusions of which I have already referred to, and a most useful summary of the various theories that have been propounded to explain the origin of binary systems.

Although the energies of our Medallist have been devoted so conspicuously to the study of double stars, he has found time for work in other fields. In his younger days he computed orbits of a number of comets, including the definitive orbit of Comet 1896 III, and he made measures with the micrometer of the 36-inch of the positions of these bodies as well as of the satellites of the outer planets, the novæ in Perseus and Gemini, and the knots that were visible on Saturn's rings soon after our passage through their plane in 1907. As chairman of the publication committee of the Astronomical Society of the Pacific he has for long been responsible for that society's most useful periodical, valued throughout the astronomical world for its early notice of much of the important work of the Pacific Coast observatories. For several years he has taken a leading part in the moulding of the policy of the great observatory which he has served throughout his astronomical life and of which he is now director.

Dr. Aitken has earned for himself a great reputation as a lecturer and as an exponent of the complicated truths of our science in a way that can readily be understood by those not well versed in the particular branch of it under review. There are not many of us here who have had the privilege of hearing him, but we look forward with lively anticipation to the George Darwin lecture which he has promised to give us in May. The presentation of the Medal is deferred until that occasion.

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